AGRICULTURAL RESEARCH INSTITUTE
PUSA

H. B. TUKEY

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

VOLUME 49

H. B. Tukey, Editor
Michigan State College,
East Lansing, Michigan

Published by the Society
June, 1947

INDIAN AGRIC. RES. INST.

W. F. HUMPHREY PRESS INC.
GENEVA, N. Y.

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OFFICERS AND COMMITTEES

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Vice-President...J. E. Knott
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L. E. Scott, *Vegetable Crops*
L. C. Chadwick, *Ornamental Horticulture*
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W. P. Judkins
C. E. Russell

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

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*As revised and adopted at the Boston meeting, December 29, 1946.

BY-LAWS

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers:* The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

SOCIETY AFFAIRS

RESUMÉ OF THE MEETING OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE, BOSTON, MASSACHUSETTS, DECEMBER 27, 28, AND 29, 1946

The American Society for Horticultural Science held its annual meeting in a three-day session at the Copley-Plaza Hotel in Boston, Massachusetts, December 27, 28, and 29, 1946 in twelve sectional meetings and one joint session, together with two evening sessions.

The nature of the discussions and the interest in the various fields of horticulture are shown by the titles of the sessions, as follows: Pomology, cultural; Small Fruits; Vegetables — Herbicides, growth regulators, pesticides; Vegetables — potatoes, root crops; Pomology — physiology; Vegetables, general; Vegetables — breeding; Pomology — fruit thinning, hormone sprays, orchard herbicides; and Floriculture and Ornamental Horticulture.

Round table discussions dealt with extension methods and with teaching methods.

Officers elected for 1947 are as shown on page vii. The banquet and social evening was in charge of the New England group, with Dr. A. F. Yeager as chairman and toastmaster, held in Horticultural Hall of the Massachusetts Horticultural Society. It was in this building on September 10, 1903 that the American Society for Horticultural Science was projected, with six individuals in attendance. At the Boston meeting a membership of 1,000 was announced.

TREASURER'S REPORT FOR 1946

Receipts

Dues	$ 5,165.53	
W. F. Humphrey Press (PROCEEDINGS, reprints, cuts, etc. sold during 1946)	5,684.81	
Vaughan Seed Stores, Chicago (for Vaughan award)	1,000.00	
A. & P. Company (reimbursement for expenses to Marketing Committee meeting, Chicago)	1,158.36	
		13,008.70
On hand December 31, 1945		9,761.74
		$22,770.44

Expenditures

Printing PROCEEDINGS — volume 47	$ 3,509.36	
Printing Reprints of volume 46	333.88	
Printing Programs — Boston meeting	97.50	
W. F. Humphrey Press — mailing, commission, etc.	586.07	
Halftones and etchings	1,338.46	
Stamps — mailing programs, letters, proofs, etc.	226.00	
Campus Press — programs, envelopes, etc.	157.16	
Clerical assistance	631.85	
Secretary's fee, and expenses to meetings	569.94	
Telephone charges — Michigan State College	14.73	
Telephone charges — W. F. Flory re program	10.75	
Society bond	30.00	
Mineographing, supplies, etc.	65.86	
Refunds on PROCEEDINGS	51.00	
PROCEEDINGS purchased for resale	32.00	
Expenses of members of Marketing Committee to Chicago meeting	1,158.36	
Bank charges	16.36	
		8,829.28
On hand December 20, 1946 —		
East Lansing State Bank	$ 398.06	
Lincoln-Alliance Bank, Geneva	13,543.10	
		13,941.16
		$22,770.44

H. B. TUKEY
Secretary-Treasurer

REPORT OF THE AUDITING COMMITTEE

Report of the Auditing Committee, acting for W. F. Pickett of Arkansas, and W. H. Upshall of Vineland, Ontario;

We hereby certify that we have examined the accounts of this Society to the best of our ability and have found them in order.

HORACE A. CARDINELL
CHARLES L. HAMNER

January 20, 1947

BUSINESS MEETING

REPORT OF THE EXECUTIVE COMMITTEE

1. Careful consideration has been given to all suggestions received from members of the Society for its general welfare.

2. The report of the Secretary-Treasurer and the finances of the Society have been reviewed.

3. The report of the special committee (W. H. Alderman, H. C. Thompson, and H. B. Tukey) appointed at the last meeting of the Society to study the Constitution and By-Laws of the Society relative to distributing the load of the Secretary-Treasurer was reviewed and the following changes in the By-Laws of the Society recommended to the Society for adoption:

a. Add Section 14:
"The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting."

b. Section 1 — line 9.
Delete "edit, publish, and distribute the PROCEEDINGS and other publications."

c. Section 4 — line 2.
Change to "including the Secretary and the Editor."

d. Section 5 — line 4.
Change "Secretary" to "Editor."
Add: "The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.
"The committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing, and distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee."

4. The committee recommends that the Auditing Committee be authorized to secure the services of a competent auditor to help in the auditing of the books of the Society.

5. The committee places the following in nomination for members of the Nominating Committee: W. H. Alderman, Chairman; H. A. Rollins, A. M. Binkley, W. C. Barnes, V. T. Stoutemyer, Kenneth Post.

The report of the committee was adopted, and the proposed changes in the Constitution and By-Laws were voted upon separately and approved.

CHANGE IN TIME OF MEETING

It was voted that it is the sense of the meeting that the Christmas Holiday Season is a poor time of year during which to hold the annual meeting, but that in trying to find a time more favorable it should be kept in mind that it is best to keep the biological groups together.

COMMITTEE ON JUNIOR BRANCH MEMBERSHIP

It was voted that the President appoint a committee to promote and develop Junior Branch Memberships within the Society. The Committee as appointed is: E. C. Stair, Chairman; A. P. French, W. P. Judkins, C. E. Russell.

UNITED HORTICULTURE

It was voted that the American Society for Horticultural Science approves the plan of organization and objectives of UNITED HORTICULTURE and commends this undertaking to its members as meriting participation and support.

REPORT OF THE RESOLUTIONS COMMITTEE

The American Society for Horticultural Science expresses its warm appreciation and thanks to its officers for their able conduct of its affairs during the year, to all the committees, and especially to the Program Committee, W. S. Flory, Chairman; and the local Arrangements Committee, A. F. Yeager, Chairman.

Thanks are extended to the management of the Copley Plaza Hotel for its facilities for the meeting, to the American Association for Advancement of Science, to the Massachusetts Horticultural Society, and to all who have cooperated in the arrangements.

PAUL WORK, *Chairman*
M. A. AMERINE
STANLEY JOHNSTON

LEONARD H. VAUGHAN MEMORIAL RESEARCH AWARD

The Leonard H. Vaughan Memorial Research Awards in Horticulture for papers appearing in Volume 46 of the PROCEEDINGS are as follows:

In *Floriculture* to Dr. G. A. L. Mehlquist of the Missouri Botanical Gardens, St. Louis, for his contribution entitled, "Inheritance in the Carnation. V. Tetraploid Carnations from Interspecific Hybridization".

In *Vegetable Crops* to Dr. Charles M. Rick of the University of California, Davis, for his contribution entitled, "Field Identification of the Genetically Male-Sterile Tomato Plants for Use in Producing F_1 Hybrid Seed".

L. H. MACDANIELS, *Chairman*
F. C. BRADFORD
J. C. MILLER
W. P. TUFTS
W. B. MACK

REPORT OF THE COMMITTEE ON EDUCATION

The following report of the Committee on Education was adopted:

1 That the Committee be retained for another year.

2. That the Chairman of the Committee (M. J. Dorsey) appoint a committee from the various regions of the Society to work on the content of, First Horticultural Courses, and Courses in Training Vocational Agricultural Teachers, and report to the next annual meeting of the Society.

M. J. DORSEY, *Chairman*

REPORT OF COMMITTEE ON MAINTAINING MARKET QUALITY OF HORTICULTURAL PRODUCTS

Due to the widespread current interest in prepackaging, the Committee felt the need of holding a special meeting to discuss some of the problems involved in marketing horticultural products of interest to horticulturists and the Society. Such a meeting was made possible through and financed by the Great Atlantic & Pacific Tea Company. The meeting was held in Chicago, Illinois, at the Bismarck Hotel, September 12 and 13, 1946. After a general discussion of the entire problem of marketing quality produce and flowers, it was decided that a first step might be the compilation of an annotated bibliography on the subject in order to present a picture of what had been done and to stimulate work in the field. The outline for such a bibliography, given below, was drawn up by the committee.

BIBLIOGRAPHY ON MAINTAINING QUALITY IN PERISHABLE HORTICULTURAL PRODUCTS

I. Maturity.
    A. Methods of Measuring. 1. Physical. 2. Chemical. 3. Mechanical.
    B. Effect of Stage of Maturity on:
        1. Handling. 2. Storage. 3. Edible Quality.
II. Harvesting Procedures and Equipment as Affecting Market Quality.
III. Packing House and Conditioning Treatments.
    A. Trimming and Cleaning.
    B. Antiseptic Treatments.
    C. Waxing and Wrapping.
    D. Other Treatments.

IV. Grade Standardization.
    A. Federal, State and Commercial Standards.
    B. Maintenance of Quality.
    C. Standards of Grading.
V. Precooling.
VI. Packaging.
    A. Containers
        1. Wholesale or Bulk Packages.
        2. Retail Packages.
VII. Transportation.
    A. Methods
        1. Rail.
        2. Motor Truck.
        3. Air.
        4. Water.
    B. Refrigeration
        1. Water Ice.
        2. Mechanical.
        3. Modified Atmospheres.
VIII. Storage.
    A. Common.
    B. Cold.
    C. Use of Modified Atmospheres.
    D. Use of Volatiles, Gases, and Fumigation
    E. Storage Sanitation.
IX. Market Handling.
    A. Wholesale.
    B. Retail.
X. Physiological Processes.
    A. Respiration.
    B. Water Loss.
    C. Vitamin Changes.
    D. Other Metabolic Changes.
    E. Growth and Ripening (ethylene, etc.).
    F. Effect of —
        1. Anti-oxidants.
        2. Other chemical materials.
XI. Market Diseases (Pathological and Physiological)
    A. Fruit.
        1. Citrus.
        2. Stone.
        3. Pome.
        4. Small.
        5. Other.
    B. Vegetables.
        1. Potatoes.
        2. Sweet Potatoes.
        3. Tomato group.
        4. Leafy.
        5. Crucifers.
        6. Cucurbits.
        7. Root Crops.
        8. Miscellaneous.
    C. Flowers, Nursery Stock, etc.
XII. Miscellaneous and General.

At the Boston meeting the following resolution was proposed and adopted by the Society.

RESOLVED; that, inasmuch as the marketing of perishable horticultural products involves many biological aspects in which horticulturists should be interested, the Secretary of the Society communicate with the Directors of the Experiment Stations and the appropriate persons in the United States Department of Agriculture, pointing out to them the value of including in their research programs, under the Hope-Flannagan legislation, projects that are concerned with means and methods of maintaining the market, edible, and nutritional quality of fruits and vegetables and the market quality of flowers; and, furthermore, recommending that they sponsor a National Project concerned with the publication of an annotated bibliography containing the work that has been completed in this field as a stimulus to research and as a means of avoiding duplication of previously completed work on this subject.

The Committee will be actively interested in obtaining support for this project and hopes to have some progress in this regard to report at the next meeting.

R. L. Carolus, *Chairman*
C. O. Bratley
L. L. Claypool
F. C. Gaylord
J. H. Gourley
F. S. Jamison
L. L. Norris
O. C. Roberts
L. E. Scott
H. C. Thompson

APPOINTMENT OF EDITOR AND BUSINESS MANAGER OF THE PROCEEDINGS

In accordance with the change in By-Laws as approved at the 1946 annual meeting, the Editorial Committee of the Society, with the approval of the Executive Committee, has appointed Dr. Harold B. Tukey, Editor-Business Manager of the Proceedings. His term of office is retroactive to January 1, 1947.

Calcium and Phosphorus Penetration in an Orchard Soil

By I. W. Wander, *Ohio Agricultural Experiment Station, Wooster, Ohio*

NUMEROUS investigations have disclosed that the application of either limestone or superphosphate on the surface of silt loam or clay soils, has resulted in very little penetration into the soil of exchangeable calcium or readily available phosphorus. For example, Robinson and Pierre (6) in West Virginia report that "from 2,550 to 4,650 pounds of surface applied limestone had, in 3½ to 4 years, not affected appreciably the 3- to 5-inch layer of soil. Brown and Munsell (2) found approximately the same rate of penetration of calcium in Connecticut soils.

Gourley and Smock (4) in a survey of Ohio orchard soils learned that when superphosphate is applied to sod orchards there is little, if any, percolation of available phosphorus below a depth of 3 inches. A deep placement of superphosphate resulted in no greater penetration of readily available phosphorus through the soil (10). It is believed by some investigators that the failure to get response from additions of phosphorus in orchards is at least partially due to the fact that most of the phosphorus is fixed in the soil before it reaches the zone of greatest root concentration (5).

Spencer and Stewart (7) working with organic and inorganic phosphates found that certain organic phosphates escape to a large extent the fixation which occurs to phosphorus applied in some inorganic forms. They felt that the deeper penetration of phosphorus from manure which had been observed by Dyer (3) and Stephenson and Chapman (8), was probably due to its organic form.

Previous investigations with the penetration of potassium (11), which is readily fixed in the top few inches of the Wooster silt loam, revealed that when potash fertilizer is placed on top of a heavy permanent mulch, fixation is practically eliminated. As a result of these studies, experiments were started to determine if a mulch would similarly affect the downward translocation of calcium and phosphorus when applied as finely ground limestone and 20 per cent superphosphate.

TREATMENTS

Treatments consisted of establishing new mulches of wheat straw in May 1944 under six Stayman Winesap apple trees of the same age (24 years) and vigor. Three trees then received 40 pounds of finely ground limestone each year for three consecutive years and three trees 20 pounds of 20 per cent superphosphate each year. Six other Stayman Winesap trees, which had been mulched since May 1941, received similar amounts of limestone and superphosphate. Six trees which remained in bluegrass sod also received the limestone or superphosphate and three trees, which were not fertilized, were retained as checks. All trees, except the unfertilized checks, received the recommended amount of nitrogen (¼ pound of nitrate of soda, or equivalent in N, per tree per year of trees age).

The mulches consisted of 200 pounds of wheat straw each year for the three years the experiment was in progress.

SAMPLING TECHNIQUE AND ANALYTICAL PROCEDURE

Soil samples were taken with a King tube to a depth of 18 inches. Five locations were sampled beneath each tree, each location divided into three 4-inch levels and one 6-inch level, the lowest. These divisions from the five sampling positions were composited at the various levels making four samples from each tree. The soil, after being air dried, was crushed with a hardwood rolling pin, screened through a 2 millimeter sieve, thoroughly mixed and stored for analysis. Samples from all treatments were taken during May and November for three consecutive years. The first set of samples were taken just preceding the start of treatments.

The exchangeable calcium was determined by leaching a 10 gram sample with 250 milliliters of neutral normal ammonium acetate, evaporating the leachate to dryness, destroying the organic matter, making the resulting salts to volume with distilled water and precipitating the calcium from an aliquot of this solution as outlined in the methods of Analysis of Association of Official Agricultural Chemists (1).

The readily available phosphorus was determined by the method outlined by Truog (9) modified to the use of a photoelectric colorimeter.

Leaf samples were taken from the mid-portion of the current years terminal growth. These samples were taken in October 1944, 5 months after treatment started and again in October 1946. It is realized that October is late to sample apple leaves at Wooster, but it was felt that sampling should be done as late as possible to eliminate, as much as practicable, contamination from spray residues. Although there may be some decline in the total phosphorus content of the leaves by October, it is believed that the results from all trees sampled at the same time would be comparable.

The leaf samples, dried at 70 degrees C, ground, mixed, and stored in paper containers in a desiccator, were wet digested with nitric and perchloric acids. The resulting salts were taken up with distilled water, made to volume, and aliquots taken for the calcium and phosphorus determinations.

The calcium was determined similarly to that described for soils and the phosphorus by the method outlined by Zinzadze (12).

RESULTS

The parts per million of exchangeable calcium in the soil at different depths under the several treatments are shown graphically in Fig. 1. The results indicate no trend in penetration of exchangeable calcium over the 3-year period due to treatment.

The parts per million of readily available phosphorus in the soil are shown in Fig. 2. In all treatments a definite increase in readily available phosphorus was noted in the top 4 inches of soil. This increase extended to the 4- to 8-inch level by the end of the second year of application on both sod and mulch. In the same length of time the 8-

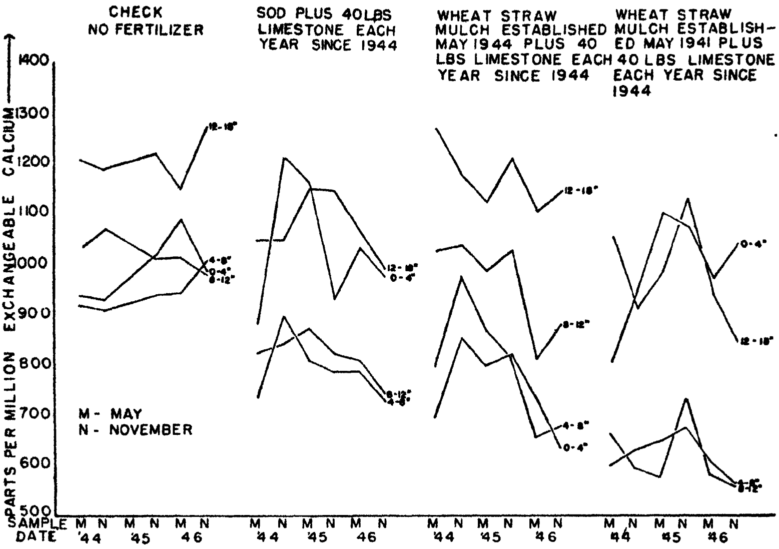

FIG. 1. The parts per million of exchangeable calcium at different soil depths following yearly applications of 40 pounds of finely ground limestone on sod, new mulch, and a previously established mulch as compared to an unlimed check.

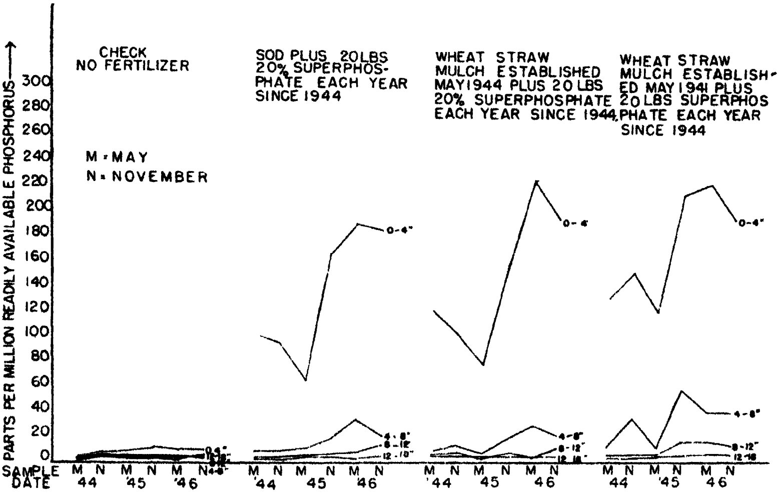

FIG. 2. The parts per million of readily available phosphorus at different soil depths following yearly applications of 20 pounds of 20 per cent superphosphate on sod, new mulch, and a previously established mulch as compared to an unfertilized check.

to 12-inch level under the previously established mulch had been increased in readily available phosphorus. No treatments used, however, resulted in any noticeable increase in phosphorus at the 12- to 18-inch soil level. The reason that the top 4 inches of soil in all treatments, except the check showed a relatively high amount of readily available phosphorus at the start of heavy applications of superphosphate, is because the treatments were established on blocks of trees which had been receiving some superphosphate since 1928. The soil analysis at the start of the heavy superphosphate treatments indicate, however, that not enough superphosphate had been used during that time to affect the 4- to 8-inch soil level.

The calcium content of the leaves in 1944 and again in 1946 is given in Table I. The analyses, averages from three trees under the same treatment, show no increase in leaf calcium from limestone applications. The total calcium in the leaves from trees under all treatments, including the check, was lower in 1946 than in 1944. This variation might be due to differences to be expected from season to season.

TABLE I—PER CENT CALCIUM IN STAYMAN WINESAP LEAVES

Treatment	Per Cent Calcium Oct 16, 1944	Per Cent Calcium Oct 10, 1946
Check, no fertilizer	1.55	1.25
Sod plus 40 pounds ground limestone each year since May 1944	1.43	1.17
Wheat straw mulch established May 1944 plus 40 pounds ground limestone each year since May 1944	1.45	1.28
Wheat straw mulch established May 1941 plus 40 pounds ground limestone each year since May 1944	1.50	1.22

The total phosphorus in the leaves is given in Table II. The amount of phosphorus in the leaves was greater at the end of the first growing season after treatment than in the unfertilized check. After three heavy applications of superphosphate, the leaves from all trees under treatment had been increased considerably in phosphorus with the leaves from trees in sod showing the greatest increase.

TABLE II—PER CENT PHOSPHORUS IN STAYMAN WINESAP LEAVES

Treatment	Per Cent Phosphorus Oct 16, 1944	Per Cent Phosphorus Oct 10, 1946
Check, no fertilizer	0.095	0.104
Sod plus 20 pounds 20 per cent superphosphate each year since May 1944.	0.124	0.256
Wheat straw mulch established May 1944 plus 20 pounds 20 per cent superphosphate each year since May 1944	0.144	0.163
Wheat straw mulch established May 1942 plus 20 pounds 20 per cent superphosphate each year since May 1944	0.103	0.147

DISCUSSION AND CONCLUSIONS

The use of finely ground limestone, either on sod or on mulch, for three growing seasons resulted in no increase of depth of penetration of exchangeable calcium on the Wooster silt loam soil. Apparently the conditions under a mulch have not solubilized the limestone and permitted the calcium to remain mobile, at least, within the time the experiment was in progress. The fact that leaf calcium was not increased also indicates that increased amounts of soluble calcium were not made available to the trees. Mulch, however, did have an effect on the deeper penetration into the soil of readily available phosphorus applied as superphosphate.

This result is in agreement with other work which showed the greater mobility and lessened fixation of organic phosphates. It is possible that the phosphorus from the superphosphate has been synthesized by the increased activity of micro-organisms under a mulch into organic phosphates and has moved in such form into the soil.

Analysis for leaf phosphorus shows that considerable amounts of phosphorus have been taken up by the trees under treatment. The leaf analysis also indicate that there is no particular benefit in obtaining a deep penetration of phosphorus into the soil since the trees take up large amounts of phosphorus even though most of it remains near the surface. A beneficial effect of the use of superphosphate with a mulch might be found, however, in a decreased fixation of the phosphorus by the soil.

SUMMARY

Results of the experiment herein reported indicate that for the Wooster silt loam:

1. A mulch had no effect in increasing the penetration of exchangeable calcium from applying 40 pounds per tree per year of finely ground limestone for a period of 3 years.
2. A mulch had a slight, but not greatly pronounced, effect in increasing the depth of penetration of readily available phosphorus into the soil when applied as 20 pounds of 20 per cent superphosphate per tree per year for 3 years.
3. The calcium content of Stayman Winesap leaves was not increased by using finely ground limestone on sod or mulch.
4. The phosphorus content of Stayman Winesap leaves was increased more through the use of superphosphate on sod than on mulch although all phosphate treatments increased leaf phosphorus.

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A Method for the Estimation of the Advancement of Vegetation by the Use of Daily Maximum Temperatures[1]

By NEWTON L. PARTRIDGE, *Michigan State College, East Lansing, Mich.*

AN important step in the evaluation of sites for fruit production in Michigan is making an estimate of the relative frequency with which injurious frosts are likely to occur on them. The influence of local topography on the frostiness of a site is well understood and accounts for the location of successful orchards on upland sites from which the cold air will tend to flow to lower spots on calm nights when frosts are likely to occur. Observation indicates there are differences also in the relative frostiness of different portions of the lower peninsula of Michigan which are usually associated with the distance of the locality from one of the Great Lakes, although other factors may have influence.

Among the conditions which are of importance in determining whether a particular frost or freeze will be injurious to a specific kind of fruit are the advancement of vegetation and the minimum temperature reached in the tissue. The duration of the cold, the rapidity with which the temperature falls and rises and the physiological condition of the plant cells as influenced by previous temperatures and growth also may be very significant in determining the amount of injury that occurs. Although the group of factors last mentioned are of importance, it is difficult or impossible on a regional basis to obtain much significant data regarding them.

The cooperative stations of the United States Weather Bureau are widely distributed throughout this area and the data obtained are readily available. Temperature data consist mainly of daily maximum and minimum readings. Sometimes notations are made regarding the occurrence of frost and, more rarely, the extent of injury to crops. As a rule, there are no phenological data and only occasionally very general remarks by a few observers as to the advancement of vegetation. Each monthly issue of "Climatological Data" contains a short discussion of the weather of the period with some mention of crop conditions. However, it is difficult to establish a close correlation between these data and the probability of injury at any particular station by any specific frost, even though the minimum temperatures are recorded. If some method could be devised whereby these temperature data could be used as the basis for a fairly accurate estimate of the advancement of vegetation, it should be possible to evaluate the local climatic differences throughout the area more closely than has been possible heretofore. Such an estimate, if reasonably accurate, would also be of considerable use to climatologists and agricultural statisticians in comparing the advancement of vegetation in different seasons and at different localities characterized by similar climatic features.

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[1] Journal Article 714, New Series, Michigan State Agricultural Experiment Station.

The author wishes to express his thanks to Mr. Stanley Johnston of the South Haven Experiment Station for the use of the data on peach bloom which he made available for this study; to Dr. Baten of the Mathematics Department of Michigan State College for his suggestions; and to Mr. Wills and Mr. Jespersen of the East Lansing Section Center of the United States Weather Bureau for their assistance and suggestions.

The literature on the effect of heat units on plant growth is extensive and has been reviewed by Gardner, Bradford and Hooker (1). There is no need to present a similar review here. However, it should be pointed out that any method for calculating an index value representing advancement of vegetation from the limited data furnished by the cooperative weather observers is certain to omit consideration of many factors which will have an influence on growth. Further, an index representing the blooming of a single fruit in Michigan might not be satisfactory for use in another region with different climatic characteristics. It might not be very satisfactory in estimating the probable date of bloom for other fruits in Michigan.

Mr. Stanley Johnston, Superintendent of the South Haven Experiment Station, has recorded the date of first peach bloom at the station each year, beginning with 1921. These data are presented in Table I. He has served as a cooperative observer for the Weather Bureau during this time. The instrument shelter is located close to the peach trees under observation, hence the data seemed particularly suited for study.

TABLE I—Dates on Which First Peach Blossoms Were Observed (Data from Mr. Johnston) and the Index Accumulated on That Date, Calculated on a Maximum Temperature Base of 40 Degrees Beginning on January 1 Each Year*

Year	Date	Index	Year	Date	Index
1921	Apr 25	1,097	1933	May 2	873
1922	May 3	958	1935	May 3	745
1923	May 17	965	1936	May 11	862
1924	May 9	660	1937	May 7	772
1925	May 9	1,047	1938	Apr 19	780
1926	May 15	736	1939	May 10	994
1927	Apr 29	752	1940	May 17	783
1928	May 14	925	1941	Apr 28	732
1929	May 2	805	1942	Apr 27	726
1930	May 3	869	1943	May 18	951
1931	May 9	735	1944	May 10	813
1932	May 6	876	1945	Apr 9	783

*Note: All Elberta fruit buds were killed in 1934 by low winter temperature.

The primary objective was to discover a suitable method for calculating an index for measuring the advancement of vegetation from the Weather Bureau data, checking it against the blooming dates of the peach for these 24 seasons and determining the amount of error likely to result from its use. The index chosen for study was the accumulated total of degrees in excess of a designated maximum temperature.[2] Since there were no data as to the relative usefulness of indices based on different maximum temperatures or beginning with different dates, indices were calculated for periods beginning January 1, February 1, March 1 and April 1 and ending with the date of peach bloom observed each season, using base maximum temperatures of 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48 and 50 degrees. The four starting dates and the 12 base temperatures thus involved the calculation of 48 indices for each of the 24 seasons for which data was available. Forty-eight series of indices were thus obtained, some of which, presumably, represented the seasonal development of the peach blossom at South Haven more closely than others. The averages of the 24 seasonal indices obtained by each method of calculation are presented in Table II, and, naturally, are larger for the longer periods and lower temperatures than for the shorter periods and higher temperature bases.

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[2] The usual method of calculation was used to obtain the accumulated total. For example, with a base maximum temperature of 40 degrees F and daily maximum temperatures of 41, 48, 56, 40, and 35 degrees F the amounts to be accumulated would be 1, 8, 16, 0 and 0 respectively. Thus 40 would be subtracted from each daily maximum temperature through the date on which peach bloom first occurred and the remainders would be accumulated from day to day, but nothing would be subtracted from the total on those days with maximum temperatures of less than 40 degrees.

TABLE II—TWENTY FOUR YEAR AVERAGES OF INDICES ACCUMULATED TO DATE OF PEACH BLOOM, SOUTH HAVEN, MICHIGAN, CALCULATED ON VARIOUS BASE MAXIMUM TEMPERATURES AND DATES

Based on Maximum Temperature (Degrees)	Date From Which Calculated			
	Jan 1	Feb 1	Mar 1	Apr 1
28	1,913	1,706	1,472	985
30	1,700	1,533	1,344	915
32	1,494	1,366	1,219	845
34	1,301	1,207	1,096	775
36	1,129	1,062	979	706
38	978	931	869	639
40	842	812	766	572
42	725	704	671	508
44	623	608	584	448
46	532	522	504	391
48	451	445	431	338
50	378	374	365	289

As was to be expected, from the presence of important variable factors in addition to the one considered, there were considerable differences between the totals for the different seasons in each of the series. Since it seemed likely that the series with the least variability between the annual values would prove most satisfactory, coefficients of variability were calculated for each of the 48 series of data and are presented in Table III. In general, the lower the base temperature

TABLE III—COEFFICIENTS OF VARIABILITY OF INDICES SHOWN IN TABLE II

Based on Maximum Temperature (Degrees)	Date From Which Calculated			
	Jan 1	Feb 1	Mar 1	Apr 1
28	10.2	10.3	11.1	23.9
30	10.8	10.7	11.1	23.8
32	11.3	11.3	11.3	23.8
34	11.8	11.8	11.8	23.9
36	12.3	12.4	12.3	23.8
38	12.6	12.9	12.8	23.9
40	13.3	13.4	13.3	23.8
42	13.9	14.1	13.9	24.2
44	14.4	14.8	14.6	24.3
46	15.0	15.5	15.1	24.3
48	16.0	16.4	16.0	24.9
50	16.9	17.4	17.0	24.9

used, the smaller the coefficients of variability become. The difference between maximum and minimum values is less with the data calculated beginning April 1 than in the other series and the coefficients of variability are higher than in the others. The fact that considerable growth occurs in some seasons in March and very little in that month in others doubtless is responsible for the high variability in the seasonal calculations beginning April 1, and suggest that this date is too late to be satisfactory. However, the coefficient of variability apparently is not a good measure of the relative value of the indices, since it would be very difficult to justify the use of a maximum temperature base of 28 degrees in preference to one of 32 degrees F. Further, the use of a maximum temperature base lower than 28 degrees would probably give even lower coefficients of variability since each reduction of 2 degrees in the temperature base over the range studied resulted in a smaller coefficient of variability.

Perhaps the failure of the coefficient of variability to be of service may be due to causes similar to that illustrated by the following example. The data in Table I show that peach bloom occurred from the 99th to the 138th day of the year, the mean being 125.5 days. The standard deviation is found to be 9.4. When January 1 of the year of bloom is used as the date from which to count, the coefficient of variability is 7.5. However, if the starting date is changed to April 1, bloom occurs on the average on day 35.5, and the coefficient of variability is consequently increased to 26.5. When we start numbering the days to bloom from January 1 of the year preceding bloom, the average day of bloom becomes 490.5 and the coefficient of variability is reduced to 1.6. The larger the value of the mean, the smaller the coefficient of variability becomes provided the standard deviation remains the same.

In view of the relatively greater frequency of days with maximum temperatures in the 30's and 20's than in the 50's and 60's during early spring up to date of peach bloom, the decrease in the value of the coefficients of variability for the lower temperature bases, as shown by the data in Table III, may be due to the weighting of the groups based on the higher maxima with the additional groups that are less variable.

The measure adopted for testing the relative usefulness of the indices was to determine the average value of each of the 48 series of data and determine the deviation each season, measured in days, between the actual date of bloom and the date on which the temperature accumulations reached the average value. From these deviations, the arithmetical mean deviation in days was obtained for each series, which are presented in Table IV. The assumption is made that with calculations of the advancement of vegetation for other and earlier growth stages or for future years, the error in the estimate will be likely to follow the course of the deviations recorded in this series.

It should be mentioned that the value of the deviation in days was influenced by the maximum temperatures of the days included. In those years when the weather was warm at bloom, a rather wide deviation of the value of the index might be recorded as a rather small deviation in days. On the other hand, when the temperature was low at this time, a considerable number of days' accumulations might be needed to equal a rather small numerical deviation of the index. For example, assuming the maximum temperature base to be 40 degrees, if the deviation in the value of the index from the average should amount to 100, it would require 10 days with maximum temperatures of 50 degrees to furnish the accumulation to equal the deviation. In case the daily maximum temperatures were 60 degrees, 5 days would be equivalent, and 2 days would be sufficient provided their maximum temperatures were 90 degrees.

The average deviations, as shown in Table IV, are the largest when the date used to begin the accumulation is April 1, and perhaps smallest when March 1 is used. The deviations are somewhat larger for the February 1 data and larger still for those obtained by using January 1 to start the accumulation. Using the January 1 data, the smallest deviations are obtained with accumulations above the maximum temperatures of 40 to 46 degrees; for the February 1 data, from 28 to 44 degrees; for the March 1 data from 28 to 42 degrees; and for the April 1 data from 36 to 44 degrees. On the whole, there is general uniformity in the values of Table IV. The amounts range from 4.4 to 5.4 days. According to the dates of bloom (Table I), the average date of peach bloom was May 6, and the average deviation during the 24-year period was 7.5 days.

In calculations of this sort, maximum deviations as well as the average seasonal variations are of interest. According to the data on actual date of bloom (Table I), the largest deviation from the average was in 1945 when the first bloom was observed on April 9, a deviation of 27 days. The maximum deviations for each of the 48 series of calculations are presented in Table V. The largest maximum deviations were obtained when April 1 was used as the starting date, the least when March 1 was used followed by the January 1 and the February 1 data. When the accumulation began with April 1, the maximum deviations were obtained with the lowest maximum temperatures used, and the deviations decreased fairly regularly as the temperature base was increased. With the other three series, the maximum deviations tend to increase as the base maximum temperature is increased. The differences between the January 1, February 1 and March 1 data are relatively small; the April 1 data is around 75 per cent greater.

The errors involved in using an index calculated on any of the bases used are large. Nevertheless, using March 1 as a starting date and a maximum temperature of 40 degrees as a base, the average error in days to be expected in using the index for estimating when the first bloom of the peach would be likely to occur during 24 years like these, would be around 60 per cent of that inherent in using the average calendar date as the estimated time of bloom each year. When maximum, instead of average, errors are considered, the reduction when the index is used amounts to nearly 50 per cent of the error obtained through the use of the average date of bloom, 14 instead of 27 days.

Previous studies in Washington (2) and in Michigan (3) have used the maximum temperature base of 43 degrees. The Michigan studies used January 1 as the starting date, and February 1 was used in Washington. The later the date that can be used, the less labor that is involved in calculation since fewer temperature data need be consulted. The data in Tables IV and V suggest it would be at least as satisfactory to begin with March 1 as any earlier date. However, South Haven is situated on the eastern shore of Lake Michigan, and the advancement of vegetation is retarded by the cooling effect of the lake breezes coming from the west. If the seasonal events of interest come as late as the date of peach bloom, the use of March 1 for a starting date would probably be as satisfactory as any earlier time. However, blossom buds may be injured by low temperatures previous to peach bloom. There are occasional seasons when February or even January temperatures may be high enough to influence the advancement of vegetation, even at stations close to Lake Michigan. Of course, in some instances warm Januarys might precede the breaking of dormancy, but this would not be the case most years. Since this study was undertaken primarily to secure a better understanding of the conditions influencing frost or freezing injury to blossom buds, it seems probable that an earlier starting date should be chosen than March 1. Such an early date would be necessary in climatological studies where comparisons between very early seasons and later ones would be

TABLE IV—AVERAGE DEVIATION OF THE INDICES IN DAYS

Based on Maximum Temperature (Degrees)	Date From Which Calculated			
	Jan 1	Feb 1	Mar 1	Apr 1
28	5.2	4.5	4.4	5.3
30	5.2	4.5	4.4	5.2
32	5.1	4.5	4.4	5.1
34	4.9	4.6	4.4	5.1
36	4.8	4.5	4.5	5.0
38	4.7	4.6	4.6	5.0
40	4.6	4.7	4.5	4.9
42	4.6	4.6	4.5	5.0
44	4.5	4.6	4.7	5.0
46	4.5	4.7	4.8	5.1
48	4.8	4.8	4.7	5.1
50	5.0	5.2	4.8	5.4

TABLE V—MAXIMUM DEVIATIONS OF THE INDICES, IN DAYS

Based on Maximum Temperature (Degrees)	Date From Which Calculated			
	Jan 1	Feb 1	Mar 1	Apr 1
28	12	13	11	25
30	11	13	11	25
32	12	14	12	24
34	12	14	12	24
36	13	15	13	24
38	13	15	13	24
40	14	15	13	23
42	14	15	14	22
44	15	15	14	22
46	15	15	14	21
48	15	15	14	20
50	14	17	14	20

necessary throughout the period previous to the last spring frost. Under the conditions at South Haven, there seems to be no great difference in the amount of error inherent in data calculated from January 1 or February 1. It seems likely, however, that similar studies would show that January 1 might be better than February 1 for points somewhat more southerly than Michigan. Consideration of climatic conditions necessary to break dormancy might tend to complicate such studies in more southern latitudes.

The data suggest that there is quite a latitude in the selection of a maximum temperature base. It is very much easier and less time consuming for most people to subtract a multiple of 10 rather than other numbers, and fewer mistakes are likely to occur. On that account the use of a maximum temperature base of 40 degrees seems to be more practical than any other. The important point is that the same number be used throughout a series of studies, so that the various series may be compared. It would also be advantageous if all studies of this sort were made using the same starting date and temperature base, as far as local factors may permit.

The possible usefulness of calculations of this sort extending over a considerable number of years are indicated by the data presented in Tables VI and VII. In each case the index has been calculated on a maximum temperature base of 40 degrees beginning January 1. The dates on which the index first reached a stated amount are given in Table VI and the value of the index on certain designated dates are given in Table VII. Perhaps one form or the other may be more ad-

TABLE VI—DATES ON WHICH INDEX REACHED INDICATED VALUES (ACCUMULATIONS BEGINNING JANUARY 1 WITH MAXIMUM TEMPERATURE BASE OF 40 DEGREES)

Year	100	200	300	400	500	600	700	800	900	1,000
1921	2-16	3-8	3-16	3-21	3-27	4-3	4-6	4-12	4-19	4-22
1922	2-23	3-12	3-25	4-5	4-8	4-14	4-20	4-26	5-2	5-5
1933	3-21	4-7	4-19	4-22	4-27	5-2	5-5	5-8	5-15	5-19
1924	4-6	4-15	4-22	4-26	5-2	5-7	5-12	5-17	5-23	5-28
1925	3-7	3-20	3-27	4-7	4-11	4-16	4-21	4-24	4-28	5-7
1926	3-23	4-17	4-25	5-2	5-6	5-9	5-13	5-18	5-21	5-25
1927	3-11	3-16	3-31	4-9	4-15	4-18	4-27	5-3	5-7	5-10
1928	3-13	3-25	4-4	4-12	4-21	5-1	5-4	5-9	5-14	5-17
1929	3-14	3-24	4-3	4-6	4-9	4-21	4-27	5-1	5-10	5-14
1930	2-21	3-6	3-17	4-6	4-11	4-17	4-27	5-1	5-4	5-7
1931	3-23	4-9	4-14	4-18	4-22	5-2	5-6	5-14	5-18	5-24
1932	2-10	3-16	4-4	4-10	4-20	4-23	4-29	5-4	5-7	5-13
1933	1-22	3-7	4-1	4-10	4-16	4-20	4-27	4-30	5-4	5-10
1934	3-15	4-5	4-10	4-19	4-27	5-1	5-4	5-6	5-9	5-12
1935	3-15	3-22	3-27	4-9	4-18	4-25	4-28	5-9	5-13	5-19
1936	3-23	3-27	4-14	4-24	4-29	5-4	5-8	5-10	5-13	5-17
1937	3-4	4-5	4-16	4-21	4-25	4-30	5-3	5-9	5-13	5-19
1938	2-17	3-19	3-22	3-27	3-31	4-13	4-16	4-21	4-26	4-30
1939	2-13	3-10	3-23	3-31	4-17	4-24	4-27	5-4	5-7	5-11
1940	4-3	4-15	4-23	4-29	5-5	5-10	5-14	5-18	5-21	5-26
1941	3-30	4-6	4-10	4-13	4-16	4-20	4-27	4-30	5-4	5-6
1942	3-20	3-26	4-5	4-14	4-18	4-24	4-27	4-29	5-2	5-6
1943	3-12	3-29	4-6	4-12	4-24	4-29	5-5	5-9	5-16	5-22
1944	2-5	3-24	4-10	4-20	4-24	4-30	5-3	5-10	5-13	5-16
1945	3-9	3-16	3-19	3-24	3-27	4-1	4-7	4-10	4-13	4-17
1946	2-12	3-7	3-14	3-19	3-25	3-29	4-3	4-11	4-17	4-22
Average	3-6	3-25	4-4	4-11	4-17	4-23	4-28	5-3	5-7	5-11

TABLE VII—VALUES OF INDEX ON DESIGNATED DATES (ACCUMULATIONS BEGINNING JANUARY 1 WITH MAXIMUM TEMPERATURE BASE OF 40 DEGREES)

Year	2-1	3-1	3-11	3-21	4-1	4-11	4-21	5-1	5-11	5-21	5-31
1921	62	124	241	421	558	797	975	1,211	1,430	1,730	2,144
1922	32	101	188	206	354	577	720	891	1,240	1,533	1,921
1923	13	15	85	104	122	238	390	588	849	1,075	1,477
1924	13	15	27	27	54	145	296	484	695	867	1,072
1925	0	84	143	212	333	508	709	949	1,085	1,341	1,605
1926	39	58	58	84	130	160	233	396	669	906	1,217
1927	5	44	114	255	308	445	677	772	1,043	1,225	1,506
1928	16	50	65	116	232	397	500	602	869	1,121	1,332
1929	2	10	37	161	290	530	615	802	936	1,170	1,520
1930	35	194	237	323	352	518	673	817	1,190	1,412	1,633
1931	19	63	64	83	113	222	499	586	762	979	1,226
1932	94	193	198	202	279	417	550	749	967	1,267	1,564
1933	139	193	201	249	305	435	627	839	1,036	1,334	1,660
1934	80	85	91	111	133	308	425	615	987	1,310	1,623
1935	26	27	91	195	334	438	531	734	865	1,078	1,334
1936	3	15	78	85	249	283	379	575	862	1,156	1,439
1937	33	86	125	130	143	226	416	635	862	1,075	1,395
1938	15	103	105	283	524	557	809	1,031	1,301	1,518	1,805
1939	73	157	207	272	421	437	541	753	1,012	1,305	1,677
1940	1	3	3	16	81	196	281	473	627	904	1,148
1941	10	28	58	62	137	349	619	829	1,075	1,356	1,677
1942	21	22	49	133	229	370	524	929	1,115	1,384	1,719
1943	15	94	99	155	271	390	439	626	850	1,023	1,274
1944	97	136	153	168	235	314	423	634	849	1,190	1,537
1945	0	44	113	333	623	860	1,047	1,168	1,299	1,497	1,791
1946	44	125	237	447	671	802	991	1,218	1,418	1,679	2,000
Aver.	34	80	118	188	288	420	573	764	996	1,247	1,550

vantageous in bringing out certain points, but either method presents a picture of seasonal conditions over the years that will aid in estimating the relative extent of the advancement of vegetation. Although there may be inaccuracies in the comparisons, the overall view may serve a useful end for the horticulturist, the climatologist and the agricultural statistician.

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Distribution of Nitrogen in Peach Trees[1]

By E. L. PROEBSTING, *University of California, Davis, Cal.*

IN the course of a long-term covercrop experiment with several species of fruit trees at Davis it became necessary to remove the peaches. This presented an opportunity to obtain data on the amount of nitrogen contained in mature trees. The trees were of two ages, half of them planted in 1922 and the remainder in 1923. All were removed in 1942. The trees were Lovells and had made good growth and had yielded well. One tree from each of 14 plots, 7 of each age, each typical of the plot from which it came, was selected. Each tree was separated into roots, stump, branches and twigs. Each fraction was weighed and an aliquot taken for analysis. The results, expressed as dry weight and amount of nitrogen, are presented in Table I. Trees 1 to 7 inclusive, were planted in 1922 and trees 8 to 14 in 1923. There were small roots which were not recovered, which would increase both the dry weight and amount of nitrogen in the root fraction slightly, but the general order of magnitude would not be affected. Neither leaves, which presumably return their nitrogen to the soil, nor fruit or prunings, which are removed from the system, were included in the analyses. The average annual increment of stored nitrogen accumulated at the end of the experiment is seen to be about .15 pound.

TABLE I—DISTRIBUTION OF NITROGEN IN A GROUP OF LOVELL PEACH TREES AT DAVIS, CALIFORNIA

Tree No.	Root		Stump		Branch		Twig		Total	
	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)
1	147	0.55	142	0.22	688	1.40	53	0.42	1,030	2.54
2	195	0.81	161	0.40	752	1.63	81	0.65	1,188	3.49
3	163	0.71	183	0.49	643	1.53	61	0.53	1,050	3.26
4	75	0.32	120	0.29	468	1.05	44	0.40	706	2.05
5	166	0.58	170	0.48	533	1.35	80	0.80	949	3.20
6	119	0.47	125	0.32	267	0.58	41	0.35	551	1.70
7	152	0.71	144	0.34	590	1.20	30	0.70	975	2.94
8	188	1.03	194	0.44	852	1.79	65	0.48	1,299	3.73
9	206	1.30	170	0.38	709	1.69	89	0.69	1,173	4.05
10	182	0.73	130	0.26	595	1.33	74	0.65	982	2.96
11	172	0.77	153	0.32	728	1.58	67	0.42	1,120	3.09
12	128	0.58	153	0.32	555	1.29	67	0.43	905	2.62
13	185	0.71	159	0.30	665	1.49	66	0.47	1,076	2.96
14	183	0.75	138	0.36	708	1.68	72	0.55	1,101	3.35
Average.	162	0.72	153	0.35	622	1.41	67	0.54	1,007	2.99

A closely related experiment was started in 1942 in an adjacent block of Muir peaches. Two previously unfertilized trees were given 20 pounds of ammonium sulfate per tree per year for 4 years, to try to determine the fate of added nitrogen. The trees were 20 years old at the beginning of the experiment.

A pit somewhat more than 8 feet deep was dug between the treated and adjacent check trees, undercuts were made at that depth and sections of 8-inch well casing forced up into the soil. Funnels under these tubes collected leachate. Only once during the 4 years did either rainfall or irrigation wet the soil to a depth greater than 8 feet. The leachate at that time averaged 57 parts per million of nitrate under the fertilized area and 32 parts per million under the check. Although more nitrogen passed below the 8-foot level in the fertilized plot than the unfertilized one, the difference was estimated at less than 0.4 pound. While the plots were only sampled to a depth of 8 feet, it is highly probable that none of the nitrogen was leached beyond the root zone. Total nitrogen was determined in 2-foot increments to 8 feet at the beginning and at the end of the experiment. Nitrates were determined at the same depths at intervals throughout the period. On the basis of these determinations it was found that about 16.1 pounds of the 16.4 pounds of nitrogen added per tree remained in the soil at the end of the experiment.

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[1] The work reported here was made possible by a gift from the Shell Chemical Company.

The fruit is estimated to have removed a total of 6.2 pounds of nitrogen from trees Nos. 1 and 2, the fertilized trees, and 5.1 pounds from trees Nos. 3 and 4. The leaves were sampled and analyzed from time to time, but all leaves were assumed to be returned to the soil beneath each tree, and, therefore, to be part of that sample.

At the end of the experiment the trees were removed and separated into fractions. Aliquots were taken and analyzed for nitrogen. The total dry weights and amount of nitrogen are given in Table II. Tree No. 2 was small and may account for the relatively low amount of nitrogen in the fertilized trees. The residual nitrogen in the two fertilized trees was about 6.1 pounds compared with 7.4 pounds in the check trees.

TABLE II—Distribution of Nitrogen in Muir Peach Trees

Tree No.	Small Roots		Large Roots		Large Branches		Small Branches		Twigs		Total	
	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)	Dry Weight (Lbs)	N (Lbs)
1	17	0.16	153	1.09	510	1.78	89	0.75	24	0.36	793	4.14
2	10	0.08	97	0.60	210	0.67	62	0.43	14	0.22	393	2.00
3	18	0.14	170	0.95	380	1.52	73	0.45	20	0.24	661	3.30
4	12	0.11	163	1.25	510	2.09	42	0.27	33	0.38	760	4.10

In summary, the fertilized area showed 16.1 pounds of nitrogen per tree in the soil, and about 0.5 pounds in the fruit more than in the unfertilized area. On the other hand, the fertilized trees averaged about 0.6 pounds of nitrogen less than the check trees in the amount in the trees themselves. Some part of the 0.4 pound below the 8-foot level may be still in the soil, and might be added to the plus side. If it all were there, the excess would total 17.0 pounds, the deficit 0.6 pound, which would just balance the 16.4 pounds added in the fertilizer. It is more likely that most of the 0.4 pound below the 8-foot level was absorbed, leaving that amount to be accounted for. It is assumed that the 0.6 pound difference in the trees themselves has developed in the course of the experimnt. This is, of course, very unlikely, but there was no method of determining the original values. The difference even with these two uncertain elements, seems to be within the experimental error to be expected in such a trial.

The surprising fact emerges from this experiment that a very high nitrogen content has been built up in the top 8 feet of soil, constituting the major root zone, without excessive absorption or adverse tree response. In casting about for an explanation for this unusual behavior, one possibility appeared to be that a slight boron excess has interfered with nitrogen absorption. Although the fertilized trees made vigorous growth and had a higher nitrogen content in the leaves than did the checks, the fruit was normal and was not delayed in maturity to the extent usual with heavy nitrogen applications.

A conclusion that follows from these figures is that even with normal rates of fertilization, the use of nitrogen by the tree is much less than the nitrogen supplied. How long such an accumulation may be effective in maintaining an adequate level in the tree if applications are discontinued is an interesting point for further study.

The Comparison of Plot Size in a Peach Experiment[1]

By T. H. McHatton, *University of Georgia, Athens, Ga.*

It is a normal assumption that large populations over a long period of years will give more reliable results than small populations through a short period. Due to land and time requirements little work has been done along this line by pomologists. E. R. Parker, and T. D. Batchelor, working with citrus in California made a study of variations in yields between large and small populations and reported their findings in Hilgardia, 1932. They suggested that plots of eight trees sufficiently replicated or through a period of years would prove satisfactory.

In the Winter of 1932–33 there was established an experimental planting of 1,000 June-budded Elberta trees in Clarke County, Georgia on the Horticultural farm of the University. The trees were on a Cecil clay loam as uniform as it is possible to obtain in areas of that size. One of the objectives of this work was to compare the yields and growth of large and small populations through a period of 10 years.

The orchard was divided into 10 plots of 76 trees with buffers between. There was selected, randomized in each plot, six trees, designated as "special trees", the records of which were to be kept separately from the remaining 70 general plot trees. Yields were recorded in pounds under the tree at harvest and circumference was measured in inches at the end of the growing season, ½ to 2 inches above the highest soil level, unless erosion necessitated it being taken a little higher.

The general experiment was a study of the time to incorporate cover crops in Georgia peach orchards and the comparison of spring and fall applications of quickly available nitrogen, the results of which will be found in a forthcoming bulletin from the University.

Suffice it to say that in all plots the general trees and the special trees had exactly the same treatment. A study of the tables submitted will show that though the special trees grew a bit faster and produced some better than the general plot trees that the relative standing of the plots as represented by both the special trees and the general plot trees is approximately the same and when variations occur the differences are not significant.

A study of the tree survival bears out the above statement. All general plots started with 70 trees, excepting plot 1 which had 68. The number of trees from which the final figures were compiled is shown in the tables. Many things happened during the 10 years. Some terraces were relocated, some trees were untrue to name, some died from an application of paradichlorobenzine during their early life, others were injured and removed for various causes so that at the end of the experiment the number of trees varied from 25 to 47, per plot. When a tree was removed for any reason its records were dropped and do not appear in the final results. Each plot started with 6 special trees or a total of 60 in all 10 plots, 52 of which survived through the 10 years.

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[1] Published with permission of the Dean of College of Agriculture, University of Georgia as a partial report of a forthcoming bulletin.

The yields obtained in this experiment are a matter of great interest. The tables show only the averages for all trees in the plot and give

TABLE I—AVERAGE YIELD IN POUNDS PER TREE PER PLOT

Plot No.	1	2	3	4	5	6	7	8	9	10
No. Trees	25	34	34	35	29	34	36	47	30	28
General Plot Trees										
Year										
1936	70.31	75 69	55.14	50 72	30.86	69 15	58.85	62 39	46 94	64.99
1937	25.94	24.74	21.71	30.84	9 85	21.91	22 76	35.46	32.54	16.94
1938	269 44	276 67	259 30	263 41	144.48	269 74	245.22	261 68	222 08	215.91
1939	90.16	187.26	141 74	195 40	129 69	210 29	202 69	200.87	153.07	104.41
1940	324.20	323.91	271.15	355.06	258.03	384 24	397 59	412 55	371.67	261.54
1941	230.84	310 76	301 56	341 46	255 14	363 12	305 05	310 91	258 73	224 29
1942	226.36	238.47	218.00	245.89	179.62	341 38	311.42	267.28	237.63	160 32
Average yield per tree for seven years	176 75	205 36	181.23	211.83	143.95	237.12	220 51	221.59	188 95	150.05
Plot No.	1	2	3	4	5	6	7	8	9	10
No. trees	5	5	5	6	4	6	5	4	6	6
Special Trees										
Year										
1936	99 70	96.31	44.72	70 84	29.74	73.37	87 81	82 80	69.93	64 98
1937	32.10	32 75	74 54	39 95	5 25	25.58	22.25	45.81	24 54	26 67
1938	355 19	342 00	291.95	307.75	181 88	287.92	354 00	293 00	272.08	224 17
1939	99.80	228 40	193 00	200.17	131 75	195 67	235.40	174 25	174.16	128.00
1940	386 80	432.00	384.40	455.83	324.25	434.00	355 20	484.50	351 00	371 50
1941	328 60	306 20	339 60	370 50	297 50	353 00	290.60	371.25	350.17	210.67
1942	234.80	266.00	343 00	342 33	312 25	413.83	458.40	443 75	212.17	288.00
Average yield per tree for seven years	205 28	243 38	238 88	255 24	183 23	254.77	257 66	270.77	193 44	187.66

TABLE II—AVERAGE YEARLY CIRCUMFERENCE IN INCHES

Plot No	1	2	3	4	5	6	7	8	9	10
No. Trees in Plot	25	34	34	35	29	34	36	47	30	28
General Plot Trees										
Year										
1936	11 16	11 09	10.38	10.72	10.22	10 66	10.66	10.82	10.38	10.06
1937	13.19	13.64	13 11	13.58	11.36	13 45	13.91	14 12	13.44	13.37
1938	16.28	16.68	16 16	16.51	13.01	16 60	16 38	16.51	15.73	15.31
1939	18.27	19.00	18 24	18.27	15.66	19 24	19.22	19.50	18 31	17 30
1940	20 27	20 65	20 23	20.83	17 17	21 39	21 19	21 39	20.52	19 19
1941	21.33	22 04	21 66	22 54	19.63	23.28	22.85	22.34	21 47	20.12
1942	22 79	23 31	22 59	23.28	21.49	24.01	23.47	23.49	22.43	21 04
Plot No.	1	2	3	4	5	6	7	8	9	10
No. Trees in Plot	5	5	5	6	4	6	5	4	6	6
Special Trees										
Year										
1936	11.50	12.75	11.10	12.19	6.96	10.72	10.79	10.49	10.27	10.17
1937	15.00	15 70	14.33	15.46	11.06	14.21	14.70	14.50	13.25	13.92
1938	19.25	19 35	17.25	18.17	13 50	17.21	17.70	17.25	16.25	16 08
1939	20.00	21.08	19.80	20 63	16.25	19.46	20 85	19.30	18.96	18.38
1940	22.40	22.75	22.15	22 95	18.50	21.46	23.05	22.06	20.96	20 54
1941	23.50	23.65	23.20	24 29	20.00	23.92	24.15	22.94	22.13	21 21
1942	25.15	25.05	24.55	24.58	20.69	24.38	24 85	24.13	22.88	22.00

no indication of what has happened to individual plants. The individual variation in yield between the trees in the same plot and under the same conditions has been great. When a statistical study of yields was made of the general plot trees and the special trees the correlation was found to be .837 ± .19.

In working out the correlation between circumference and yield in the general plot trees it was found to be .834 ± .246 and the same correlation in the special trees was .780 ± .076. Neither of the results appear of any great moment but are of enough similarity to indicate that the smaller group of special trees compares generally to the behavior of the larger group.

It is believed that the results obtained from this work with peaches warrant the statement that plots of from six to eight plants should produce trustworthy data upon which to predicate general orchard recommendations. This conforms to statement of Parker and Batchelor in relation to the population of citrus plots. Is it a fair question to ask just what has been the population in past pomological experiments? Have we not been looking upon the plant as the individual instead of the bud? If it is accepted that the bud is the individual in the plant world then our pomological populations have been enormous and we can only render our experimental work more accurate through increasing replications or number of years.

Further Experience with the Chemical Thinning of Wealthy Apples During Bloom and its Influence on Annual Production and Fruit Size[1]

By M. B. Hoffman, *Cornell University, Ithaca, N. Y.*

Preliminary tests (1, 2) on the thinning of Wealthy apples at blossom time with a DN[2] spray have shown that the treatment would increase the size of the fruit and in addition promote annual bearing in this biennial variety. Following these results a more extensive test was started in 1943 on similar trees in the same orchard.

This orchard is located in Orange County, New York in the lower Hudson Valley and is planted on Dutchess silt loam, which is considered one of the best fruit soils of the area. The trees were 22 years old, vigorous and have always received excellent commercial care. Solid rows of Wealthy and Delicious alternate on the diagonal. There are about 230 Wealthy trees in the block. Eighty-two of these trees scattered throughout the block blossomed very heavily in 1943. All remaining Wealthy were in an "off" year condition, either completely barren of bloom or having only a few spurs producing flowers.

Seven of the "on" year trees were selected at random and reserved as checks. The treatments listed in connection with Table I were applied to the 75 remaining "on" year trees. There were two groups of five trees each in different sections of the block which receive treatments A, B, D, E, F, G and H. Only one group of five trees was available for treatment I. In 1944 one tree receiving treatment G was removed because of crown injury probably initiated by winter killing. Results on only nine trees are averaged for this treatment.

The various treatments applied in 1943 were made to recheck the matter of concentrations for these Wealthy and to compare the effect of single and duplicate applications on the degree of thinning and amount of leaf injury. Elgetol was used in treatments A, B, D, E, F, and G for this purpose. Treatments F and G were identical except that the trees in treatment G were sprayed with a gun. Applications for all other treatments were made with a six nozzel broom. Powders or dry forms of DN were used in treatments H and I. One pound of these dry forms contains approximately the same amount of toxicant as 1 quart of Elgetol, 6 to 7 ounces depending on the material.

Observations, fruit set counts and harvest records in 1943, indicated that Elgetol at a concentration of 1 quart per 100 gallons or its DN equivalent in other forms applied during the day that all spur flowers opened resulted in the most satisfactory degree of thinning. The thinning of trees in treatment A which received two applications of the

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[1] The interest and cooperation shown in this work by Mr. Eugene Bacher, White Cloud Farm, Rock Tavern, New York, is deeply appreciated. He has given generously of his time, allowed the use of many trees and supplied spray equipment and labor during the course of this and other similar tests. Much credit is also due to Mr. J. D. Van Geluwe, Dr. A. Van Doren, Dr. L. J. Edgerton, and Mr. D. R. Murdock, who have assisted with the spraying and record-taking on numerous occasions.

[2] An abbreviation for Dinitro-O-Cresol or its salts.

TABLE I—THE EFFECT OF CHEMICAL THINNING AT BLOSSOM TIME ON THE BEARING HABIT AND SIZE OF THE WEALTHY APPLE OVER A 4-YEAR PERIOD

Treatment*	No. Trees	1943		1944		1945		1946		1943 to 1946
		Ave No. Bu Per Tree	Ave No. Fruits Per Bu	Ave No. Bu Per Tree	Ave No. Fruits Per Bu	Ave. No Bu Per Tree	Ave No. Fruits Per Bu	Ave No. Bu Per Tree	Ave No. Fruits Per Bu	Total Ave Bu Per Tree
A	10	19.2	172	5.0	120	16.4	106	20.7	120	61.3
B	10	12.6	136	13.0	144	8.6	101	18.7	119	52.9
C	7	19.9	280	0.1	—	19.4	179	0.2	—	39.6
D	10	12.9	125	23.7	164	6.8	88	22.0	137	65.4
E	10	18.3	246	0.5	—	15.7	107	17.9	114	52.4
F	10	21.0	144	13.3	135	15.7	104	20.6	141	70.6
G	9	16.7	142	12.0	143	15.0	96	21.0	117	64.7
H	10	17.0	147	9.7	129	13.3	101	21.7	130	61.7
I	5	16.6	138	8.4	132	12.7	106	21.8	122	59.5

*KEY TO TREATMENTS

1943

A—Two applications: 1 pint Elgetol per 100 gallons, May 13, 30 per cent bloom open
1 pint Elgetol per 100 gallons, May 15, full bloom.
B—Two applications: 1 pint Elgetol per 100 gallons, May 13, 30 per cent bloom open.
1 quart Elgetol per 100 gallons, May 15, full bloom.
C—Check, no sprays
D—Two applications: 1 quart Elegtol per 100 gallons, May 13, 30 per cent bloom open
1 quart Elgetol per 100 gallons, May 15, full bloom.
E—One application: 1 pint Elgetol per 100 gallons, May 15, full bloom
F—One application: 1 quart Elgetol per 100 gallons, May 15, full bloom.
G—One application: 1 quart Elgetol per 100 gallons, May 15, full bloom.
H—One application: 1 pound ammonium salt DNOC per 100 gallons, May 15, full bloom.
I—One application: 1 pound DN No. 2 per 100 gallons, May 15, full bloom.

1944

All trees except checks and treatment: E—One application: 1 quart Elgetol per 100 gallons, May 10, 1944, full bloom.

1945

All trees except checks—one application: 1 quart Elgetol per 100 gallons, April 13, full bloom.

1946

All trees except checks—two applications: 1 quart Elgetol per 100 gallons, April 29, delayed full bloom. 1 pint Elgetol per 100 gallons, May 1, flowers on terminals open.

weaker concentration of 1 pint per 100 gallons was insufficient as indicated by the count of 172 fruits per bushel. A large proportion of these fruits were 2¼ to 2½ inches.

Trees in treatment B also received two applications. The concentration of the second or full bloom spray on May 15th was increased to 1 quart per 100 gallons. This resulted in fruit of good commercial size but possibly over thinned the trees to some extent. However, four of the ten trees in this treatment are somwhat smaller in size than the average for the orchard which accounts for some of the relatively low average yield per tree.

The checks, treatment C, produced a heavy crop of very small fruit. Treatment D consisted of two applications of Elgetol both containing 1 quart per 100 gallons. The first application on May 13th prevented set by many of the center spur flowers and the full bloom spray 2 days later destroyed the lateral spur flowers. More than half of the crop developed from bloom on the previous seasons terminals which opened after the second spray was applied. The fruit was large in size but the trees were over-thinned. Only 12 apples developed per 100 blossoming spurs. This treatment caused more leaf injury than any of the others. The growing points of some spurs on the weaker wood toward the center of the trees were killed.

Very little thinning resulted from treatment E. This was a single application of 1 pint of Elgetol per 100 gallons applied at full bloom May 15th. At harvest the apples were almost as small as those produced by checks. Counts averaged 246 fruits per bushel. This treatment has thinned Wealthy satisfactorily in other orchards where the trees were located on imperfectly drained land and making rather poor growth but it did not prevent the excessive setting of fruit in this vigorous block.

Treatments F, G, H, and I may be considered together. They were all single applications applied at full bloom May 15th. The concentration was double that used in treatment E; that is, 1 quart of Elgetol per 100 gallon or its approximate equivalent of DN in dry form. These 34 trees produced a full, uniform crop of good commercial size. Leaf injury following these treatments was moderate. One month after bloom the trees had a better leaf surface both from the standpoint of leaf size and number of leaves than did the checks or those trees which were thinned less (treatments A and E). Preventing an excessive fruit set seemed to favor early leaf growth.

In 1944 the amount of bloom on the 81 trees was rather closely associated with the degree of thinning resulting from the various treatments the previous year. There was a negligible amount of bloom, less than 1 per cent, on the seven check trees and the 10 trees in treatment E. A very heavy bloom amounting to about 75 per cent was produced by trees receiving treatment D. These two applications of Elgetol at a concentration of 1 quart per 100 gallons eliminated most of the spur bloom in 1943. The amount of bloom on trees in the other six treatments was estimated to range from 5 to 35 per cent.

Considering the results obtained in 1943 it seemed needless to continue all of the original treatments. Yet, previous experience (*2*) indicated that these Wealthy would profit by some thinning, mainly to avoid clusters on blossoming spurs and promote fruit size of the current crop. All trees in treatments A, B, D, F, G, H, and I were sprayed with a single application of Elgetol at a concentration of 1 quart per 100 gallons the first day of full bloom May 10, 1944.

With the exception of treatment A which had a very light bloom and treatment D which had a heavy bloom these trees bore from one-half to three-fourths of a full crop in 1944. There was a serious drouth in this area during the 1944 growing season. The rainfall during May and June was 1 inch less than normal and only 3.81 inches of rain fell during July and August. This represents a total deficit of 6 inches for the four-month period. In spite of these dry conditions the fruit on the sprayed trees developed fairly satisfactory size except in the case of the trees in treatment D which were carrying a heavy crop.

The season of 1945 was the second "on" year for these Wealthy since the start of the test. All trees blossomed heavily except those in treatment D which bore a full crop in 1944. Trees in all treatments except the checks were sprayed with Elgetol at a concentration of 1 quart per 100 gallons the first day of full bloom, April 13, 1945. This date of bloom was one of the earliest on record for the area. Although the weather had been unseasonably warm for a week prior to bloom and throughout the bloom period there was a change to much cooler conditions on April 18th. Light to moderate frost occurred on the nights of April 22 and 23rd. Some damage to the crop occurred in this block. The killing of young fruits was largely confined to the low limbs but frost markings were quite common on apples at the 5- to 8-foot level. It was estimated that this frost occurring 8 days after blossom thinning probably reduced the crop about 2 to 4 bushels per tree. The orchard is located on a slope of about 20 degrees. The frost damage was confined to the lower portion of the block where about half of the trees in each treatment were located.

Soil moisture was abundant throughout the 1945 season. The total precipitation for May to August inclusive was 17.84 inches which exceeded the normal by 3.07 inches. The treated trees bore about 80 per cent of a full crop. With the exception of a light set on many of the low limbs, it was uniformly distributed and of excellent size. The check trees carried an overload of fruit and more than half of the crop was below 2½ inches in spite of the good growing conditions.

Considering the biennial bearing habit of Wealthy, 1946 was to have been an "off" year for all of these 81 trees. The small reduction in set caused by frost in 1945 was not sufficient to promote fruit bud formation by the checks. All treated trees, however, blossomed heavily. The bloom development was about 2 weeks earlier than normal. Following several days of unseasonably warm weather 75 to 80 per cent of the spur bloom was open on April 24th. If the weather had continued warm the spray would probably have been applied April 25th but bloom development was delayed for 4 days by cold conditions. A spray of 1 quart of Elgetol per 100 gallons was applied April 29th when practically all spur bloom had opened. At this time anthers in many of the lateral spur flowers were shedding pollen. Generally under such conditions one application will not reduce set satisfactorily. For this reason a second application of 1 pint of Elgetol per 100 gallons was made on May 1st when the flowers developing on the terminal growth of the previous season opened. As the season advanced fruit set counts showed that 15 per cent of the bearing spurs had set more than one apple. This was probably the result of delaying the full bloom application during the period of unfavorable weather, April 25th to 29th. Although cool temperature existed during this period, fruit setting apparently made some progress and the full bloom application on April 29th did not reduce the set to the same extent that it had in previous years. Some hand thinning was employed in July to break clusters on spurs bearing more than one fruit. This was the only season over the 4-year period when the bloom treatments were supplemented with any hand thinning. The 1946 crop was the largest of the four crops produced by the treated trees. The fruit was of good commercial size but the fact that some of the thinning to obtain this size was not accomplished until mid-summer may result in a reduced bloom in 1947.

Under the conditions existing in this orchard thinning the Wealthy crop at blossom time with DN sprays has caused the trees to bear commercial crops annually, in contrast to the distinct biennial bearing of unsprayed trees. In addition fruit of commercial size has been produced without the expensive and laborious operation of hand thinning which has been always necessary with bearing Wealthy. The total average yield per tree for the various treatments over the 4-year period exceeded that of the checks by as much as 12 bushels (treatment E) up to 31 bushels (treatment F). Much of this variation in total yield for the different groups is due largely to the initial treatments made in 1943. The increased total yield which all treatments show over checks occurred in 1944 and 1946 when the checks were barren.

It would seem possible that such trees as these might be maintained indefinitely in an annual bearing condition with a DN bloom spray provided unfavorable weather did not interfere seriously with the timing of the application. In most seasons, under New York State conditions, there is only one day during the development of Wealthy bloom when a single application of the spray reduces set satisfactorily. This is the first day of full bloom or when practically all spur flowers have opened and before the anthers of the lateral spur flowers have started to shed pollen. A rapid development of bloom during warm sunny weather which lasts through the first day of full bloom has provided the most ideal conditions for the treatment.

These DN Sprays usually cause some injury to the foliage present at bloom time. The amount seems to vary from year to year and to be associated in some way with seasonal conditions. In this test the most severe foliage injury occurred in 1943 and 1945, when there was an abundant supply of soil moisture due to frequent spring rains. With dryer conditions in 1944 only moderate injury developed. In 1946 when an extremely dry period preceded bloom these sprays caused very little or no visible injury to foliage. This was true in both the Hudson Valley and in Western New York areas where six different varieties were used in thinning treatments. Even in cases where rather severe foliage injury has occurred, such as with treatment D in 1943, no serious after-effects have been noted in the growth of leaves, wood or fruit. It is possible that the prevention of an excessively heavy set of fruit may save more reserves than would be contributed by the early spur leaves which under normal conditions usually remain small in size.

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Studies in Thinning Peaches with Blossom Removal Sprays

By F. W. SOUTHWICK, L. J. EDGERTON, and M. B. HOFFMAN,
Cornell University, Ithaca, N. Y.

REPORTS of Batjer and Moon (1), Hoffman and Van Doren (5), and Murneek and Hibbard (6) indicate that weak concentrations of sodium dinitro cresylate (Elgetol) applied as sprays are effective in thinning peaches at blossom time. In an effort to obtain more data on the commercial value of this material and others a number of tests were conducted in peach orchards in the Hudson Valley and Western New York in 1945 and 1946.

Major emphasis was placed on comparative tests of some of the commercially available dinitro compounds both in liquid and water soluble powder form. The materials tested were the liquid forms Elgetol (20 per cent sodium dinitro cresylate), and Krenite (20 per cent sodium dinitro cresylate), and the powders DN No. 1 (40 per cent dinitro-ortho-cyclohexylphenol), DN No. 2 (40 per cent dinitro-ortho-cresol), DN No. 111 (20 per cent dicyclo-hexyl amide salt of dinitro-ortho-cyclohexylphenol) and water soluble powder containing 40 per cent of ammonium dinitro-ortho-cresylate. Although the toxicant in Elgetol and Krenite is identical they are prepared by different manufacturers and their formulation may be quite different. The amount of toxicant in the materials varies from to 6 to 7 ounces per quart or pound, depending upon the material, except for DN No. 111 which is approximately one-half this strength per pound. Since the reports of Burkholder and McCown (2), Greene (4), Schneider and Enzie (7), and Davidson, *et al.* (3) indicate that naphthalene acetic acid and similar types of materials may reduce the set of apples, sodium naphthaleneacetate (App-L-Set) and methyl naphthaleneacetate were tested, also.

Orchards possessing trees of uniform age, size and bearing capacity were selected for these tests. Each treatment was applied to consecutive trees in a given row. The number of trees from which detailed records were obtained are indicated in the tables presented in the text.

All the dinitro materials were applied with a single-nozzle gun at 400 to 500 pounds pressure when the trees reached approximately 95 per cent or more of full bloom. The "hormone" type materials were applied at this same stage of bloom development, petal fall, or up to 20 days after full bloom. None of the materials caused the development of any visible foliage injury at the concentrations employed.

Following the application of these materials from 200 to 400 flowers were counted per tree from two typical limbs. Set records were obtained after the June drop was completed by counting the fruits remaining where flower counts were made and calculating the per cent set. Yield and size records were obtained whenever possible.

HUDSON VALLEY RESULTS

In 1945 unusually warm weather prevailed in March and during the first two weeks in April. Consequently, peach trees in the Lower

Hudson Valley blossomed in early April, approximately, a month ahead of their average blooming date. The weather at blossom time, however, was warm and sunny and conducive to heavy fruit setting.

A block of uniform, mature Golden Jubilee peach trees with an exceptionally heavy bloom were selected. The trees reached approximately 95 per cent of full bloom on the morning of April 10th and were given drenching sprays containing various dinitro materials during the afternoon of the same day. From the data presented in Table I it is apparent that all the materials tested were very effective in reducing the set.

TABLE I—THE INFLUENCE OF FULL BLOOM APPLICATION OF DINITRO SPRAYS ON THE SET, SIZE AND YIELD OF GOLDEN JUBILEE PEACHES

Treatment (Concentration Per 100 Gals)	Fruit Set Records Jun 27, 1945		Fruit Yield Records, Aug 1, 5, 7, 9, and 12, 1945			
	No. Trees	Per Cent Set	No. Trees	Ave No. Fruits Per Bushels	Prevailing Size	Ave No. Bushels Per Tree
Check—unthinned	10	13.3	5	232	2⅜	1.9
Elgetol, 1 pint	10	3.0	5	156	2⅝	1.7
Krenite, 1 pint	9	4.7	5	148	2¾	1.4
DN No. 1, ½ pound	12	6.7	5	166	2⅝–2¾	1.3
DN No. 2, ½ pound	9	5.4	5	148	2¾	1.3
NH salt DNOC, ½ pound	9	1.5	5	136	2¾–2⅞	0.5

This reduction in set was reflected in the size of the fruit at harvest. All treatments resulted in fruits which were at least ¼ inch larger than the unthinned checks. From the yield data it is apparent that the size of the crop was somewhat reduced by all the materials tested but this reduction was not considered excessive, except on those trees sprayed with ammonium dinitro-ortho-cresylate, since there was a larger proportion of fruit of marketable size on the sprayed thinned trees.

Table II represents some fruit set data obtained in 1946 from an 8-year-old block of Elberta trees. The spring of 1946 was somewhat similar to the one which occurred in 1945. The weather in March was unseasonably warm and although some cool weather occurred in April the blooming season of peaches in the Lower Hudson Valley was about 2 weeks earlier than average. The flower buds on these Elberta trees commenced to open on April 14th. However the weather turned cool the following week and full bloom was not reached until April 23rd. The sprays were applied at this time.

TABLE II—THE INFLUENCE OF FULL BLOOM APPLICATIONS OF SOME SPRAY MATERIALS ON THE SET OF ELBERTA PEACHES (FRUIT SET RECORDS JULY 8, 1946)

Treatment (Concentration Per 100 Gals)	No. Trees	Per Cent Set
Check—unthinned	5	35
DN No. 1, ½ pound	8	18
DN No. 2, ½ pound	7	24
DN No. 111, 1 pound	8	33
Elgetol, 1 pint	8	19
Krenite, 1 pint	8	15
App-L-Set, 10 ppm	5	29

Of the materials tested equivalent concentrations of toxicant in Elgetol, Krenite, and DN No. 1 reduced the set to about one-half that occurring on the unthinned checks. DN No. 111 and App-L-Set at the concentrations used were ineffective, whereas, DN No. 2 was intermediate between the two extremes in its effect on fruit set. Although no size or yield records were obtained it was felt by observers at harvest time that the thinning obtained from Elgetol, Krenite, and DN No. 1 was excellent from the standpoint of development of good fruit size and yield. From this test it appears that Krenite may have been more effective in reducing the set of peaches than the other materials.

WESTERN NEW YORK RESULTS

In 1945 tests were conducted on some 9-year-old Elberta and 10-year-old Valiant peach trees in Niagara County. The trees were located on a heavy soil not well adapted to peaches. They were not growing very vigorously and possessed only a moderate number of fruit buds.

The unusually warm weather in March and early April made for early blooming of fruit trees in this section of New York State, also. In fact on April 14th sweet cherries were past the full bloom stage and peach trees in this orchard near Lake Ontario had an estimated 75 per cent of their flower buds open. However, on April 15th the temperature dropped sharply with minimum temperature for the next 6 days in the low thirties. The skies were overcast for much of this period with some precipitation of rain and snow. The temperature rose to 60 degrees F or slightly above for very brief periods between April 15 and 21st. Bee activity in the peach orchards was practically nonexistant during this period. The trees reached an estimated 95 per cent of full bloom on April 21st and were sprayed on that day. No frost injury to the flower buds was evident. The temperature at the time of spraying was approximately 34 degrees F. Due to the fact that the bloom was not heavy, 6 days of extremely cool weather had prevailed prior to full bloom and previous experience in the orchard (5) the materials (Elgetol, DN No. 1, and DN No. 2) were applied at half the usual strength used elsewhere, except for one plot of Valiant and Elberta trees which received Elgetol at the rate of 1 pint per 100 gallons of water. The data obtained are given in Table III.

In this experiment DN No. 1 appeared to be superior to the other materials tested as far as its ability to reduce the set. The best fruit size was present on those trees receiving this treatment, also. No explanation can be given for the failure of Elgetol and DN No. 2 to thin appreciably at equivalent concentrations. In fact Elgetol at twice the toxicant concentration of DN No. 1 did not thin as markedly as DN No. 1. A reduction in yield occurred where spray thinning was accomplished.

In 1946 some experiments were conducted on some Elberta and Valiant trees in an orchard adjacent to Lake Ontario in Wayne County. The trees in this orchard were growing very vigorously. During the previous season the trees were fertilized generously with nitrogen

TABLE III—THE INFLUENCE OF DINITRO SPRAYS APPLIED AT FULL BLOOM ON THE SET, SIZE AND YIELD OF VALIANT AND ELBERTA PEACHES

Treatment (Concentration Per 100 Gals)	Fruit Set Records (Jul 9, 1945)		Fruit Yield Records (Aug 30 and Sep 3, 1945)			
	No. Trees	Per Cent Set	No. Trees	Ave No. Fruits Per Bushel	Prevailing Size	Ave. No. Bushels Per Tree
			Valiant Peaches			
Check—unthinned	5	17.8	4	237	2⅜	3.1
Elgetol, 1 pt	5	13.9	4	201	2½	2.8
Elgetol, ½ pt	5	16.6	5	227	2⅜	3.2
DN No. 1, ¼ lb	5	11.1	5	184	2½	2.7
DN No. 2, ¼ lb	5	16.9	5	209	2⅜–2½	3.0
	Fruit Set Records (Jul 9, 1945)		Fruit Yield Records (Sep 10, 1945)			
			Elberta Peaches			
Check—unthinned	5	14.5	5	217	2⅜	4.3
Elgetol, 1 pt	5	9.0	5	169	2⅝	2.6
Elgetol, ½ pt	5	11.3	5	190	2½	4.2
DN No. 1, ¼ lb	5	6.7	5	148	2¾	2.4
DN No 2, ¼ lb	5	11.3	5	191	2½	3.6

and cultivated frequently until early August. The 1945 shoot growth was extremely rank and many shoots had grown up to 3 feet in length and possessed numerous lateral branches. The Elberta trees in this highly vegetative condition had only a moderate number of flower buds. Valiant which is a variety which tends to set heavier in this orchard than Elberta had an abundance of flower buds.

The weather in March 1946 was unusually warm as had been the case in 1945. However in April the weather turned cool as is common near Lake Ontario and the peaches did not commence to bloom until the last week in April. The Valiant trees had reached an estimated 20 per cent of full bloom on May 2nd and since the weather was cool the following week they did not reach full bloom until May 10th when they were sprayed. The Elberta trees in the same orchard reached full bloom on May 13th.

From the results with Valiant presented in Table IV it can be seen that at equivalent toxicant concentrations DN No. 1 and DN No. 111 were more effective in reducing the set than either Elgetol or DN No. 2. None of the "hormone" type materials were effective on reducing the set at the concentrations used when applied at or within 20 days after full bloom. The most desirable size at harvest was obtained from those trees receiving equivalent amounts of DN No. 1, DN No. 2, and DN No. 111. Except for those trees receiving DN No. 1 the yield of the treated trees does not appear to be significantly lower than those obtained from the unthinned checks.

The Elberta trees, Table V, were suitably thinned by all the dinitro materials. From the yield data it is apparent that a concentraion of 1½ pints of Elgetol per 100 gallons of water was too severe thinning. This concentration reduced the yield considerably more than the other treatments, but the fruit on these trees was not larger than that obtained from trees moderately thinned. The checks and those sprayed with

TABLE IV—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT FULL BLOOM AND LATER ON THE SET, SIZE, AND YIELD OF VALIANT PEACHES

Treatment (Concentration Per 100 Gals)	Fruit Set Records (Jul 2, 1946)		Fruit Yield Records (Sep 6 and 9, 1946)			
	No. Trees	Per Cent Set	No. Trees	Ave No. Fruits Per Crate*	Prevailing Size	Ave No. Crates Per Tree
Check, unthinned.	10	49.0	6	259	2⅜	2.9
Elgetol, ½ pint	10	40.8	—	—	—	—
Elgetol, 1 pint	10	31.9	9	246	2⅜–2½	2.7
DN No. 1, ½ pound	10	15.4	7	159	2¾–2⅞	2.0
DN No 2, ½ pound	9	26.7	9	191	2⅝	2.7
DN No. 111, 1 pound	10	17.4	9	157	2¾–2⅞	2.5
App-L-Set, 20 ppm	5	53.9	—	—	—	—
App-L-Set, 40 ppm.	5	54.7	—	—	—	—
Methyl Ester NAA, 10 ppm	5	50.1	—	—	—	—
Methyl Ester NAA, 20 ppm	5	52.6	—	—	—	—
App-L-Set, 40 ppm (petal fall—May 17)	5	43.4	5	257	2⅜	2.5
App-L-Set, 40 ppm (May 30)	5	52.7	5	273	2⅜	2.5

*A crate held approximately 1.20 bushels.

TABLE V—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT FULL BLOOM AND LATER ON THE SET, SIZE, AND YIELD OF ELBERTA PEACHES

Treatment (Concentration Per 100 Gals)	Fruit Set Records (Jul 2, 1946)		Fruit Yield Records (Sep 20 and 27, 1946)			
	No. Trees	Per Cent Set	No. Trees	Ave No. Fruits Per Bushel	Prevailing Size	Ave No. Bushels Per Tree
Check*	10	45.6	10	166	2⅝	3.1
Elgetol,** 1 pint	10	20.5	10	140	2¾	2.8
Elgetol,** 1½ pint	10	13.5	10	120	2⅞	1.6
DN No 1** ½ pound	10	15.8	10	124	2⅞	2.3
DB No 2**, ½ pound	10	18.4	9	128	2⅞	2.6
DN No. 111,** 1 pound	9	16.8	9	124	2⅞	3.1
App-L-Set,* 20 ppm	5	37.7	5	164	2⅝	3.7
App-L-Set,* 40 ppm	5	37.4	5	177	2½–2⅝	2.6
App-L-Set,* 40 ppm (petal fall)	5	50.4	5	175	2½ 2⅝	3.6
Methyl Ester NAA,* 10 ppm	5	50.0	—	—	—	—
Methyl Ester NAA,* 20 ppm	5	41.7	—	—	—	—
Methyl Ester NAA,* 10 ppm (May 30)	5	52.2	—	—	—	—

*All trees were hand thinned in July.

**A few peaches were removed from those trees sprayed with the DN materials to separate fruits in close proximity, although hand thinning was not necessary on those trees to produce desirable size.

App-L-Set and the methyl ester of naphthalene acetic acid were hand thinned in early July after the set records had been taken. Consequently, size differences between the spray thinned and check trees were not as great as one would anticipate otherwise. However, it does demonstrate the superiority of good spray thinning over hand thinning as far as fruit size is concerned. The grower, also, had hand thinners remove a few peaches from those trees sprayed with the dinitro materials to separate fruits in close proximity. Such thinning was unnecessary as far as development of good fruit size was concerned and only served to lower the yield. The concentration of App-L-Set and methyl naphthalene acetate applied at full bloom, and 17 days later (8 days after petal fall) were of no value in reducing the set.

DISCUSSION

Due to the adverse spring weather conditions in New York State in 1945 the apple crop was considerably below average. The reduction in crop was due to frost injury or poor pollinating weather or a combination of both. A somewhat similar situation in 1946 again reduced the size of this crop below the 1940 to 1944 average even though an unusually heavy bloom was present in most orchards in the state as a result of the extremely small crop in 1945. Peaches on the other hand, bore crops in 1945 and 1946 above the 1940 to 1944 average and thinning of peach trees to obtain suitable size was necessary in the commercial peach areas of the state.

The fact that the peach orchards in New York are located in areas which are seldom injured by spring frosts was partially responsible for this condition. Also, in 1945 most peach trees had passed the full bloom stage in the Hudson Valley and had reached from 50 to 75 per cent of full bloom in Western New York before extremely poor pollinating weather occurred in April and May. In other words a good crop had set before poor weather conditions could interfere with pollination and fertilization. However, practically all of the commercial peach varieties grown are self-fruitful and bagging experiments indicate that they may set full crops in the absence of pollinating insects.

The experiments show that all the dinitro compounds tested may be satisfactory for blossom thinning of peaches when applied at approximately full bloom. Of the materials tested DN No. 1 has been the most consistent in its ability to reduce set. From 3.0 to 3.5 ounces of soluble toxicant was usually the most desirable concentration for the dinitro materials. However, it has been found from other experiments, not included herein, that young bearing trees of the variety Elberta, which is not generally a heavy setting variety, that 3.0 to 3.5 ounces of toxicant may overthin. The same situation may exist on older trees if the number of live flower buds per foot of shoot growth is limited. Trees on poorly drained soils may be so lacking in vigor that they may be in this condition. However, trees may be so vigorous that flower bud formation may be reduced as appeared to be the case in the Elberta block in Wayne County. On the other hand, some varieties such as Veteran and Halehaven, for example, which tend to set heavy crops may require from 4.5 to 5 ounces of toxicant or slightly more for adequate blossom thinning. Neither App-L-Set containing the sodium salt of naphthalene acetic acid or methyl naphthaleneacetate showed any promise as a chemical peach thinner at the concentrations used at full bloom and up to 20 days thereafter.

Blossom thinning in 1945 and 1946, which were years of ample soil moisture supply generally tended to reduce the total yield although it did not in 1944 (5) when drought conditions existed. It should also be pointed out that blossom thinned trees are apt to have a higher proportion of fruit of marketable size than is the case on unthinned or hand thinned trees. The reduction in thinning and harvesting cost must be considered, also.

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An Early Post-Blossom Thinning Agent for York Apples

By W. S. Flory, Jr. and R. C. Moore, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

A spray mixture consisting of a specially prepared latex of polyethylene polysulfide (Goodrite p.e.p.s.) and a complex product formed by the reaction of zinc dimethyl dithiocarbomate (zimate) with cyclohexylamine, developed at the Boyce Thompson Institute by B. F. Goodrich chemists, was tested by the Virginia Experiment Station as a possible post-blossom fruit thinning agent for apples. When this complex was used in Delaware, throughout the 1945 season, it resulted in an almost complete drop of fruit. Consequently, it was the possible utilization of a part of this fruit-drop effect in early post-blossom thinning of apples, which was explored at Blacksburg, Virginia in 1946.

Three treatments were applied to York trees: (a) One spray, 10 days after full-bloom; (b) two sprays, 10 and 20 days, respectively, after full bloom; and (c) three sprays, 10, 20 and 30 days, respectively, after full bloom. Three trees received each treatment, and a fourth lot of three trees was carried as a check. Two pounds of the polysulfide, plus 1 pound of the zimate-cyclohexylamine complex, were used in each 100 gallons of spray, along with 3 pounds each of lime and lead arsenate. About 25 gallons of spray were applied to each of the 35-year-old trees used.

Data were secured in two ways: (a) At blossoming, 100 strong clusters were marked on three branches of each tree. After the June drop counts of fruit sets from these 300 blossom clusters per tree, were made; and (b) total tree yields from the different treatments were compared.

Table I offers comparisons as between the checks and the different treatments. The data are somewhat "out of line" where the two latex sprays were applied. In general, however, the latex sprays seem effective in their thinning results. Thinning was about as desired where one spray was applied. Three "latex" sprays gave comparable results, with but slight additional thinning. Data (not presented here) on fruit size and grade indicates an improvement in both of these items, as might be expected, from the thinning effect. All pertinent data have

TABLE I—Summary of Data Taken Following Application of the Post-Blossom "Thinning" Sprays to York Apple Trees*

Treatment	Fruit Sets Per 300 Blossom Clusters	Tree Yields (Bushels)
Checks	94	32.7
1 "Latex" spray**	43	24.9
2 "Latex" sprays†	60	29.0
3 "Latex" sprays‡	38	22.8

*There were three trees in each treatment. The figures presented equal averages of the data from the three trees involved in each treatment.

**April 26.

†April 26, May 6.

‡April 26, May 6, May 16.

not yet been considered in detail, but it appears that the "off-trend" in results in the case of the two-spray treatment may be correlated with, and at least partially explained by, the vigor and biennial bearing of the trees in these treatments, as seen from the past performance records of these trees.

It is apparent that if an effective post-blossom thinning spray were available that the hazard of over-thinning with blossom sprays prior to a late frost might be eliminated. Also if the thinning were early enough, it still might have little adverse effect on bud-formation for the crop of the following year. The complex used bears promise of furnishing a thinning spray with these advantages, at least for York apples.

A less extensive trial was given the material on trees and fruit of Stayman. Indications are that the same thinning trend was apparent where the latex sprays were used on Stayman, as on York, but that less thinning occurred on Stayman from comparable treatments.

An incidental observation is of interest. All trees, of both York and Stayman, receiving the latex sprays were noted to be almost entirely free, on both foliage and fruit, of cedar rust, when checked during the late summer. Other adjacent trees, which received Fermate (or in some cases other) fungicidal sprays, had foliage showing numerous rust spots. This was true whether the trees had received one, two or three latex sprays. This spray appears quite effective in controlling cedar rust.

A Spray Mixture Useful to Thin Apples After Bloom[1]

By A. L. Kenworthy, *Delaware Agricultural Experiment Station, Newark, Del.*

In 1944, tests were begun on the use of the dinitro compound sold as "Elgetol" for a fruit thinning spray. The results obtained were disappointing because of the severe leaf and twig injury resulting from its use on apples. On account of the extreme injury resulting from the use of dinitro compounds, their use was discontinued after the 1945 season. Although a few growers in Delaware still use dinitro compounds to thin apples, its use is discouraged and a non-caustic spray recommended.

In 1945, a testing program of compounds having low phytotoxicity was started in cooperation with the B. F. Goodrich Company. The compounds before field trials were to be entirely non-phytotoxic at concentrations used and have hormone activity that would indicate a possible use as a fruit thinning spray. Several compounds have been tested some of which hold considerable promise. This report concerns a spray mixture that was being tried as a scab spray and was found to be effective in reducing fruit set.

In 1945, two spray materials were tested in combination for scab control. One of the materials was polyethylene polysulfide, now known as "Goodrite p.e.p.s." The other material was a complex product formed by the reaction of zinc dimethyl dithiocarbamate (Zimate) and cyclohexylamine. The Goodrite p.e.p.s. as received contained an excess of lignin sulfonate as a wetting agent. The lignin sulfonate solution was poured off and the paste used contained 50 per cent polyethylene polysulfide. The zinc dimethyl dithiocarbamate-cyclohexylamine complex was also dispersed with lignin sulfonate and made into a paste that contained 1 pound of the compound per ½ gallon. Since Goodrite p.e.p.s. itself is a good sticker, the presence of excessive amounts of lignin sulfonate has ben known to reduce the deposit of polymer.

During the season, seven applications of this mixture were applied on Delicious. When the second application after full bloom was applied, a marked dropping of the fruits was observed. Counts of fruits per tree showed that the spray mixture had reduced the average number of fruits per tree from 733 for the checks to 238 for sprayed trees. There appeared to be no relationship between the concentration of zinc dimethyl dithiocarbamate-cyclohexylamine complex and number of fruits per tree at harvest time. However, earlier dropping of the fruit was observed on trees sprayed with higher concentrations of the zinc dimethyl dithiocarbamate-cyclohexylamine complex. Neither of the materials when used alone caused any reduction in number of fruits per tree.

This spray mixture was tried on Blaxtayman in 1946. The zinc dimethyl dithiocarbamate-cyclohexylamine complex was used at the rates of 1/8 and 1/4 pounds per 100 gallons, while Goodrite p.e.p.s. was used at 2 pounds per 100 gallons. A single application was made on May 6 or 11 days after full bloom. Three trees were used per treatment. Counts made during harvest on October 24 showed that the use of 1/4 pound of the zinc dimethyl dithiocarbamate-cyclohexylamine complex with Goodrite p.e.p.s. had reduced the set to 16.6 fruits per 100 flowering spurs, while the 1/8-pound rate with Goodrite p.e.p.s., 35.8 fruits per 100 flowering spurs were set. The checks set 35.4 fruits per 100 flowering spurs.

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[1] Published as Miscellaneous Paper No. 19 with the approval of the Director of the Delaware Agricultural Experiment Station. Contribution (No. 8) of the Department of Horticulture, December 19, 1946.

Counts made on May 27, 21 days after spraying or 32 days after full bloom, indicated that both concentrations of the zinc dimethyl dithiocarbamate-cyclohexylamine complex in combination with Goodrite p.e.p.s. had reduced fruit set. The use of 1/8 pound of the complex showed 47.3 per cent set and 1/4-pound dosage showed 27.2 per cent set. The checks showed 77.6 per cent set. This indicates that the spray mixture caused an earlier dropping of fruit than from normal processes. This earlier dropping may be of a decided benefit in effecting annual bearing.

The results obtained in 1945 and in 1946 indicate that this spray mixture is capable of reducing fruit set 50 to 60 per cent and may be applied 10 to 14 days after full bloom. The proper concentration appears to be 2 pounds of polyethylene polysulfide (Goodrite p.e.p.s.) plus 1/4 pound of zinc dimethyl dithiocarbamate-cyclohexylamine complex. The results to date are very limited but are sufficiently indicative to warrant more extensive field trials to determine the effect of time of application, concentrations, and repeat applications. Its effect on other varieties is not known. Preliminary observations in 1945 and 1946 indicate that this spray mixture may reduce fruit set on peaches when applied near the shuck-fall period.

In addition to reducing fruit set, this spray mixture seems to have other advantages. It is not toxic to any plant parts, it mixes easily, and is composed of materials that have phytocidial properties.

A Comparison of Two Types of Materials for the Chemical Thinning of Apples[1]

By M. B. Hoffman, F. W. Southwick, and L. J. Edgerton,
Cornell University, Ithaca, N. Y.

Dinitro ortho cresol and dinitro ortho cyclo hexyl phenol as well as certain salts of these materials, hereafter referred to as the DNs, have been tested as bloom sprays for thinning apples (1, 5). Under New York conditions, some very good results in the thinning of such heavy setting varieties as Wealthy, Baldwin and Golden Delicious have been obtained when dilute solutions of the DNs were applied the first day of full bloom (6, 7).

Several investigators (2, 3, 4, 9) have reported that sprays of naphthalene acetic acid or its sodium salt applied during or following the bloom period would reduce fruit setting by the apple, thus producing a thinning effect.

Heavily blooming trees of each of the varieties Wealthy, Delicious, and Baldwin were sprayed in 1945 with the sodium salt of naphthalene acetic acid. Concentrations of 10 ppm and 20 ppm were used on some trees at full bloom and on others at the calyx stage. The stronger concentration at full bloom eliminated the crop on all three varieties and the other treatments, with the exception of the 10 ppm concentration at calyx, seemed to have caused excessive thinning. No fruit set records were taken because of frost injury following an early bloom.

As a result of the general crop failure in 1945 due to unfavorable weather most of the apple orchards in New York State produced a heavy bloom in 1946. Orchard tests on the chemical thinning of Wealthy, McIntosh, Delicious, and Rome Beauty were conducted. The materials used in these tests included four DN products and a preparation containing the sodium salt of naphthalene acetic acid which is distributed under the name "App-L-Set" and designated here as NaNAA.

Ten to twelve trees of each variety were included in each treatment. Six trees of the most uniform size in each treatment were used for fruit set and yield records. All blossoming points on two representative unit branches located 4 to 5 feet from the ground were counted at the time the sprays were applied. After the June drop, the total number of fruits on these branches were counted. The fruit set records in Table I were calculated from these counts.

All treatments reduced the set of Wealthy, but none of them thinned quite enough. Generally 20 fruits per 100 blossoming points will result in a commercial crop for this variety and approximately this amount of thinning is needed for good size and quality. The DN sprays applied May 21st reduced the set of the spur bloom satisfactorily but did not effect the set of flowers borne laterally on the 1945 terminal growth. These flowers opened 2 days after the application. The two concentrations of NaNAA applied at calyx on May 30th show a reversal in results to that which might have been expected. No explanation can be made for the greater reduction in fruit set by the weaker concentration applied at the same stage of development. Concentration of 15 and 20 ppm of this material applied June 11th or 12 days after calyx caused the shedding of young fruit from both spurs and terminal growths of the previous season.

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[1] The Dow Chemical Company furnished a grant for carrying out this work and supplied all the materials used in the test except the Elgetol.

TABLE I—THE EFFECT OF THINNING SPRAYS ON THE FRUIT SET BY FOUR VARIETIES OF APPLES (1946)

Treatment	No. Fruit Per 100 Blossom Points
Wealthy—Western New York	
Check, no spray	60
DN No. 1* ¾ pound per 100 gallons; first day full bloom May 21	28
DN No. 2 ¾ pound per 100 gallons, first day full bloom May 21	33
Elgetol 1 ½ pint per 100 gallons; first day full bloom May 21	30
NaNAA 10 ppm; calyx May 30	40
NaNAA 15 ppm; calyx May 30	51
NaNAA 15 ppm; 12 days after calyx Jun 11	34
NaNAA 20 ppm; 12 days after calyx Jun 11	31
McIntosh—Hudson Valley	
Check, no spray	30
DN No. 1 ½ pound per 100 gallons; second day full bloom Apr 30	23
Elgetol 1 pint per 100 gallons; second day full bloom Apr 30	10
NaNAA 5 ppm; second day full bloom Apr 30	18
NaNAA 5 ppm; calyx May 8	26
NaNAA 10 ppm; calyx May 8	19
Delicious—Hudson Valley	
Check, no spray	53
DN No. 1 ½ pound per 100 gallons; second day full bloom May 1	29
Elgetol 1 pint per 100 gallons; second day full bloom May 1	32
NaNAA 5 ppm; calyx May 8	35
NaNAA 10 ppm; calyx May 8	24
NaNAA 10 ppm; 9 days after calyx May 17	30
Rome Beauty—Western New York	
Check, no spray	48
DN No. 1 ½ pound per 100 gallons, first day full bloom May 24	25
DN No. 2 ½ pound per 100 gallons; first day full bloom May 24	28
DN No. 111 1 pound per 100 gallons; first day full bloom May 24	29
Elgetol 1 pint per 100 gallons, first day full bloom May 24	38
NaNAA 5 ppm; calyx May 30	53
NaNAA 10 ppm; calyx May 30	54
NaNAA 10 ppm; 12 days after calyx	45
NaNAA 15 ppm; 12 days after calyx	47

*DN No. 1—40 per cent Dinitro ortho cyclo hexyl phenol
DN No. 2—40 per cent Dinitro ortho cresol
DN No. 111—20 per cent Dicyclo hexyl amide salt dinitro ortho cyclo hexyl phenol
Elgetol—20 per cent sodium salt of dinitro ortho cresol
NaNAA—Preparation containing sodium salt of naphthalene acetic acid

The fruit set records for McIntosh checks indicate that these trees were not in great need of thinning. However, the records were taken from relatively low limbs where fruit setting was not so heavy as on the more vigorous wood in the upper two-thirds of the trees. The two DNs used at approximately the same concentration on the second day of full bloom gave variable results. Elgetol reduced the set considerably more than did DN No. 1. Elgetol seems to be more toxic to McIntosh than to some other varieties. The reduction in set caused by the NaNAA treatments was associated somewhat with the stage of development and the concentration. The concentration of 10 ppm at calyx resulted in the most satisfactory thinning of any treatment. The fruit was very evenly distributed over the entire bearing surface. The set on this treatment consisted mostly of single fruits of good color and size while that on the check trees was heavily roped on many limbs resulting in a large per cent of small, poorly colored apples.

The Delicious trees used in this test were interplanted row for row with Wealthy. Under these conditions the Delicious have always set heavily when they bloomed. Hand thinning has been a standard practice. Most trees as individuals have borne some fruit each year, but for any given tree the crop has been in one section of the tree one year and in the other section the next season. In other words there has been distinct alternate bearing of all fruiting wood although the total annual production from the block would not emphasize this fact.

During the past three years the grower has been successful in thinning these Delicious with a spray containing 1 pint of Elgetol per 100 gallons applied the second day of full bloom. The application on Delicious has been made the day after the Wealthy were sprayed. The rate of bloom development of these two varieties in this orchard is practically identical. Both reach full bloom at the same time. Delaying the spray on Delicious for one day seems to be necessary to avoid over thinning. This treatment has practically eliminated the necessity for hand thinning Delicious and is causing a more uniform development of bloom over the entire fruiting area of individual trees.

According to fruit set records in this test DN No. 1 and Elgetol were about equally effective in thinning, but at harvest time there were more small apples on the trees sprayed with DN No. 1. The NaNAA sprays on Delicious gave similar results to those obtained on McIntosh. With respect to fruit set, size, color and quality of crop the calyx application at a concentration of 10 ppm was the best treatment on Delicious.

The test on Rome Beauty was conducted on a 30-year-old block of uniform trees which had developed, during the past 10 years, a distinct tendency toward alternate bearing. The bloom was heavy in 1946. All of the four DN treatments applied May 24th, the first day of full bloom, reduced the set below that of the checks. The Elgetol was less effective than DN No. 1, DN No. 2, and DN No. 111. The row sprayed with Elgetol was an outside row bordered on the opposite side of an orchard road by a mixed block of McIntosh and Wolf River. The possibility of more cross pollination on this outside row before the sprays were applied than on succeeding rows in the Rome block may explain why Elgetol did not reduce set to the same degree as did the other DN materials. Somewhat more thinning would have been desirable on all DN treatments.

Fruit setting by these Rome trees was not affected by any one of the four NaNAA treatments although the same concentration of this material applied at similar stages of development reduced the set of Wealthy, McIntosh, and Delicious. This is difficult to understand. Possibly an application closer to the period of full bloom or stronger concentrations at about the calyx stage would have accomplished some thinning.

Records on yield and fruit size from the Delicious and Rome tests are given in Table II. It was not possible to obtain this data for the Wealthy and McIntosh. The per cent of the crop from each treatment coming within the various size grades was obtained by sorting 5 bushels of fruit taken at random from each of six trees receiving the particular treatment. The sorting was done by passing all fruits through standard fruit sizing rings. The percentage figures are based on numbers of fruits, not on volume.

TABLE II—THE EFFECT OF CHEMICAL THINNING ON YIELD AND SIZE OF APPLES (1946)

Treatment	Ave No Bu Per Tree	Ave No. Fruits Per Bu	Per Cent			
			–2¼ Inches	2½ Inches	2¾ Inches	3 Inches +
Delicious—Hudson Valley						
Check, no spray	25.0	162	52.4	30.2	16.5	0.8
DN No. 1 ½ pound per 100 gallons, second dav full bloom May 1.	22.8	129	15.8	38.6	33.1	12 4
Elgetol 1 pint per 100 gallons, second day full bloom May 1	21.8	118	2.8	29.8	43.1	24.2
NaNAA 5 ppm, calyx May 8	23.1	138	23.3	40.2	34.0	2.4
NaNAA 10 ppm, calyx May 8	21.3	96	8.4	18 6	34.8	38.2
NaNAA 10 ppm, 9 days after calyx May 17	24.5	120	12.3	38.2	35.6	13.8
Rome Beauty—Western New York						
Check, no spray	23.2	169	33.5	40.5	20.6	5.3
DN No. 1 ½ pound per 100 gallons, first day full bloom May 22	22.1	124	3.1	15.2	31.4	50.2
DN No. 2 ½ pound per 100 gallons, first day full bloom, May 22	23 0	128	6.3	21.5	35.2	36.9
DN No. 111 1 pound per 100 gallons, first day full bloom, May 22	20.1	127	8.7	20.1	34.2	36.9
Elgetol 1 pint per 100 gallons, first day full bloom, May 22	22 9	143	13.2	34.4	32.3	20.0
NaNAA 5 ppm, calyx, May 30	23.2	169	—	—	—	—
NaNAA 10 ppm, calyx, May 30	20.5	161	—	—	—	—
NaNAA 10 ppm, 12 days after calyx, Jun 11	22.5	155	—	—	—	—
NaNAA 15 ppm, 12 days after calyx, June 11	24.2	167	—	—	—	—

There was a deficiency of rain in New York State throughout the late winter and early spring of 1946. Orchards were unusually dry at bloom time. Under these conditions the DNs caused very little or no leaf injury. The concentrations of NaNAA used in these tests did not visibly deform or damage foliage in any way.

DISCUSSION

Various formulations of the DNs have been used for several years to thin apples. These materials have given fairly consistent results when the application is timed to coincide with the development of full bloom on such heavy setting varieties as Wealthy, Baldwin, Golden Delicious, Rome Beauty and Yellow Newtown. However, in the case of other varieties, notably, McIntosh, R. I. Greening, Northwestern Greening, and Delicious the results have been rather erratic. This may be due to improper timing of the spray with respect to the processes of pollination and fruit setting. Also, it seems likely that the DNs are more toxic to the flower parts of some varieties than to others.

It has been shown that the sodium salt of naphthyl acetic acid will cause the shedding of flowers during bloom and will also induce the abscission of young fruits at the calyx stage and later, well past the period of pollination. There are many factors that will influence the drop of young fruits; such as thoroughness of pollination, the supply of water, nitrogen, carbohydrates and possibly other materials not yet identified (8). These factors will vary with the season and orchard conditions and in this way may greatly influence the amount of thinning caused by a given treatment of a material like the sodium salt of naphthyl acetic acid. If the effects of such a material should prove consistent from year to year it would seem to have definite advantages for the chemical thinning of some apple varieties.

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A Method for Evaluating the Effectiveness of Growth Substances in Delaying Apple Abscission

By L. J. EDGERTON, *Cornell University, Ithaca, N. Y.*

MANY different plant growth substances have been tested to determine their effectiveness in retarding preharvest drop of several apple varieties, but for McIntosh no material has been found which has proved to be much superior to naphthaleneacetic acid. There has been a desire to find a material or combination of materials which would be more satisfactory on McIntosh as the period of effectiveness of naphthaleneacetic acid is comparatively short and rather careful timing of the application is necessary to obtain the greatest commercial benefit of that short period.

In recent tests reported by Batjer and Marth (1) 2,4-dichlorophenoxyacetic acid was found to be considerably more effective than naphthaleneacetic acid in preventing drop on Winesap. The possibility of a similar effectiveness of 2,4-dichlorophenoxyacetic acid on McIntosh was naturally pursued. In some unpublished work carried out in the Hudson Valley in 1945 tests were made to determine the effectiveness of this chemical, alone and in combination with other materials, in delaying the harvest drop of McIntosh. The 2,4-dichlorophenoxyacetic acid was found to be ineffective. Similar results have since been published by Batjer and Thompson (2).

Because of certain obvious limitations attendant upon the extensive testing of materials in a commercial orchard at harvest time, particularly with McIntosh where heavy drop may occur on trees treated with an ineffective material, the desirability of some other method for evaluating the effectiveness of materials on a given variety is apparent. One of the early observations which led to the idea of using plant growth substances for preventing drop of apple fruits was the effect of these compounds on the persistence of petiole stubs on treated cuttings (3). This suggested the possibility of evaluating the effectiveness of a compound in retarding fruit drop on a given variety by observing its effect on the persistence of leaf petioles on the same variety.

MATERIALS AND METHODS

Trees of the varieties McIntosh, Stayman and Winesap having an abundance of shoots or "water sprouts" on the lower main limbs within easy access of the ground were selected for these tests. Shoots of uniform diameter and length, with 20 to 30 leaves each were used for the treatments. The basal four or five leaves were avoided as were the young leaves near the tips which were not fully expanded. Enough shoots were selected and labelled to provide the desired number of petioles per treatment. The leaf blade was removed leaving the entire petiole attached, then the materials were applied using a small, hand-operated sprayer. An effort was made to thoroughly wet the petioles with the spray. The number of petioles persisting at successive periods following the applications were noted and drop data computed therefrom.

In order to correlate the results of the petiole abscission with fruit abscission the materials were applied to unit branches of McIntosh, Staymen and Winesap and their effect on retarding preharvest drop observed. Because of the comparatively small number of fruits involved in each treatment the results of the test on fruit abscission are not presented.

Results and Discussion

The materials used in the first test with McIntosh were some whose effectiveness in delaying preharvest drop on that variety had previously been ascertained. The data on cumulative drop of petioles following the treatments are presented in Table I. Naphthaleneacetic acid markedly delayed the abscission of the petioles as compared with untreated controls. On the other hand 2,4–dichlorophenoxyacetic acid had little effect on the persistence of the petioles on this variety. Methyl naphthaleneacetate was included as one of the treatments since a field test in the fall of 1943 in New York had indicated that it was only slightly effective in delaying the preharvest drop of McIntosh. Gardner *et al.* (3) have also reported that this methyl ester is inferior to naphthaleneacetic acid in delaying drop. The effect of the ester on the petioles is in line with these observations.

TABLE I—Effects of Three Growth Substances on the Abscission of Leaf Petioles of McIntosh*

Treatment	Cumulative Per Cent Drop					
	Days After Treatment					
	11	17	21	25	30	36
Naphthaleneacetic Acid (30 ppm)	2	6	10	40	62	94
Methyl Naphthaleneacetate (30 ppm)	18	48	66	84	98	100
2,4-Dichlorophenoxyacetic acid (30 ppm)	36	62	75	82	100	—
Naphthaleneacetic Acid (15 ppm); and 2,4-Dichlorophenoxyacetic Acid (15 ppm)	4	16	20	54	70	98
Check	49	74	87	96	100	—

*Materials applied August 5, 1946; 100 petioles per treatment.

The combination of naphthaleneacetic acid and 2,4–dichlorophenoxyacetic acid was not as effective as naphthaleneacetic acid alone, probably because naphthaleneacetic acid was used at a concentration of only 15 ppm in this combination. A combination of these materials was also found to be no superior to naphthaleneacetic acid alone in tests on fruit drop on McIntosh in the Hudson Valley in 1945.

The results of a later test involving petioles on trees of Stayman, Winesap and McIntosh are presented in Table II. The abscission of the petioles of Stayman and Winesap which were treated with 2,4–dichlorophenoxyacetic acid was even more effectively delayed than those treated with naphthaleneacetic acid. The greater effectiveness of 2,4–dichlorophenoxyacetic acid in controlling preharvest drop of the fruit with these two varieties has been reported by Batjer and Thompson (2) and Harley *et al.* (4). The comparative effectiveness of naphthaleneacetic acid and 2,4–dichlorophenoxyacetic acid on McIntosh is in line with that reported in Table I for the earlier test. The methyl

TABLE II—EFFECTS OF SOME GROWTH SUBSTANCES ON THE ABSCISSION OF LEAF PETIOLES OF THREE VARIETIES OF APPLES*

Treatment†	Cumulative Per Cent Drop						
	Days After Treatment						
	11	16	21	27	32	36	43
Stayman							
Naphthaleneacetic Acid	0	15	25	52	60	82	100
Methyl Naphthaleneacetate	0	28	43	65	72	92	100
2,4-Dichlorophenoxyacetic Acid	0	0	0	2	7	13	25
Methyl 2,4-Dichlorophenoxyacetate	0	0	0	2	5	8	17
Amyl 2,4-Dichlorophenoxyacetate	0	0	0	3	28	43	47
Check	37	72	90	95	98	100	—
Winesap							
Naphthaleneacetic Acid	0	20	67	90	100	—	—
Methyl Naphthaleneacetate	0	46	80	97	97	100	—
2,4-Dichlorophenoxyacetic Acid	0	0	0	0	3	10	23
Methyl 2,4-Dichlorophenoxyacetate	0	0	0	3	3	7	13
Amyl 2,4-Dichlorophenoxyacetate	0	0	7	20	27	40	67
Check	23	90	97	100	—	—	—
McIntosh							
Naphthaleneacetic Acid	0	10	20	27	40	—	—
2,4-Dichlorophenoxyacetic Acid	20	67	83	93	100	—	—
Methyl 2,4-Dichlorophenoxyacetate	7	50	57	63	83	—	—
Amyl 2,4-Dichlorophenoxyacetate	13	83	87	93	100	—	—
Check	17	73	80	97	100	—	—

*Materials applied September 5, 1946; 60 petioles per treatment.
†Materials applied at concentration of 30 ppm.

naphthaleneacetate had only a slight effect in delaying petiole abscission with Stayman and Winesap.

Two esters of 2,4–dichlorophenoxyacetic acid which were tested effectively retarded the abscission of the petioles of Stayman and Winesap whereas they exhibited only slight effect on McIntosh. The limited test with these two esters in delaying the drop of fruits on Stayman and Winesap showed similar effectiveness as indicated by the data on petiole abscission.

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Further Studies with 2,4-Dichlorophenoxyacetic Acid Sprays in Retarding Fruit Drop of Winesap Apples

By L. P. BATJER and A. H. THOMPSON, *U. S. Department of Agriculture, Wenatchee, Wash.*

EXPERIMENTS performed in 1944 and 1945 (1, 2, 3) have shown considerable promise for 2,4–dichlorophenoxyacetic acid (2,4–D) as an effective chemical in retarding the harvest drop of Winesap and Stayman Winesap apples. While 2,4–D was ineffective on a number of varieties tested (2, 3) its much greater duration and intensity of effect on Winesap and Stayman Winesap as compared with naphthaleneacetic acid indicated that it had promise of replacing the latter compound as a commercial harvest spray on these varieties. The present report gives the results of more extensive experiments performed with the Winesap variety during the 1946 season.

MATERIALS AND METHODS

Spray applications were made with standard portable spray equipment and were applied with 500 pounds pressure using a single-nozzle gun with a No. 8 disc. The chemicals were dissolved in a small amount of grain alcohol before being added slowly to the water in the spray tank. One pint of a light emulsified oil per 100 gallons of water was used. All treatments consisted of 10 single, randomized trees. Experimental trees in the different orchards varied from 20 to 35 years in age and all were carrying a moderate to heavy crop of fruit.

Fruit growth measurements were made weekly on two hundred individually tagged fruits prior to and following applications of 2,4–D spray in two of the experimental blocks.

With all 2,4–D treatments applied during August varying amounts of foliage injury, confined principally to the inside portion of the trees, was obtained. This injury, which did not appear until approximately 3 weeks following treatments, was rated numerically as described in the footnote of Table I.

Fruit drop records were made at frequent intervals following applications of experimental treatments. Harvest dates were within the commercial range for the Winesap variety.

EXPERIMENTAL RESULTS

Results shown in Table I strongly indicate that within the range tested, the earlier the 2,4–D spray was applied the greater the reduction in fruit drop. It would seem evident from these data that while the September 25 spray application was highly effective yet it was significantly less effective than the previous ones. Likewise when the spray was applied September 13 it was somewhat less effective than when applied August 30 and significantly less effective than when applied August 1st. With respect to time of application these results are similar to those reported previously (2) and support the original suggestion (1) regarding the timing of 2,4–D sprays, namely that, for

TABLE I—EFFECT OF 2,4-DICHLOROPHENOXYACETIC ACID SPRAYS APPLIED AT DIFFERENT DATES ON THE HARVEST DROP OF WINESAP APPLES*

Date Sprayed	Concentration (Ppm)	Average Injury Rating†	Accumulated Drop (Per Cent) October			
			14	17	21	23
Aug 1	10	2.8	0.3	0.4	0.4	0.5 ±0.07
Aug 30	10	1.4	0.4	0.5	0.6	0.7 ±0.15
Sep 13	10	0.0	0.5	0.6	0.8	1.0 ±0.12
Sep 25	10	0.0	0.6	0.8	1.2	1.9 ±0.28
Sep 13	5	0.0	0.4	0.5	0.9	1.4 ±0.24
Unsprayed	—	0.0	1.7	4.7	11.2	18.3 ±3.57

*A naphthaleneacetic acid spray (concentration 10 ppm) applied September 25 resulted in 1.4 ± 0.12 per cent accumulated drop.

†Injury rated numerically as follows: 1—Occasional premature yellowing of leaves on shaded spurs in inner portion of tree; 2—Yellow leaves on inside of tree more numerous but not commercially serious; 3—Numerous yellow leaves on inside of tree, some brown and crisp; 4—More brown or parched leaves in evidence and some bud injury apparent on spurs with several injured leaves; injury principally confined to inside of tree; 5—Injury to leaves and buds scattered throughout tree but worse in shaded portions; size and color of fruit affected.

greater effectiveness, 2,4-D sprays be applied earlier with reference to fruit maturity than naphthaleneacetic acid.

It will be noted in Table II that injury to foliage resulted from both treatments applied during August, though this was significantly greater from the August 1 application. Fruit growth measurements showed no reduction in fruit size from any treatment except the August 1st treatment where ultimate fruit size was about 1 per cent smaller in comparison with measured fruits on unsprayed trees.

With regard to concentration of 2,4-D sprays the data in Table I and Table II show no essential difference between 5 and 10 ppm when applied the second week in September.

TABLE II—RELATIONSHIP OF CONCENTRATION TO EFFECTIVENESS OF 2,4-DICHLOROPHENOXYACETIC ACID SPRAYS APPLIED SEPTEMBER 11

Concentration (Ppm)	Average Injury Rating*	Average Accumulated Drop (Per Cent) October			
		17	25	29	30†
5	0.0	0.3	0.7	1.8	2.1
10	0.0	0.6	1.0	1.8	2.2
Unsprayed	0.0	1.3	4.7	10.2	12.8

*See footnote 2, Table 1.

†Difference necessary for significance at the 5 per cent point: 4.43.

The results presented in Table III emphasize the much greater duration of effect of 2,4-D than of naphthaleneacetic acid. Naphthaleneacetic acid, which was highly effective for a period of 25 days, began to "run out" between October 21 and 25, and by October 26 the fruits on trees receiving this treatment were dropping heavily. The data in Table III indicate that 2,4-D was not rendered ineffective when applied in combination with a lead arsenate plus cryolite spray for codling moth control. Greater foliage injury coupled with less fruit drop from this treatment may possibly have been due to the much greater gallonage of spray material used. This spray was primarily applied for codling moth control, and for this purpose, it is commercial practice to apply from 90 to 100 gallons to large trees of the size used in this experiment. Where the 2,4–D was used singly (Table III) less than one-half this amount of spray was used.

TABLE III—RELATIVE EFFECTIVENESS OF NAPHTHALENEACETIC ACID AND 2,4–DICHLOROPHENOXYACETIC ACID, THE LATTER APPLIED SINGLY AND IN COMBINATION WITH A LEAD ARSENATE-CRYOLITE SPRAY FOR CODLING MOTH CONTROL*

Material	Date Sprayed	Average Injury Rating†	Average Accumulated Drop (Per Cent) October			
			14	21	25	26
2,4-D	Aug 9	2.0	0.1	0.2	0.8 ±0.13	1.7
2,4-D plus Lead-Cryolite	Aug 9	3.0	0.1	0.2	0.2 ±0.03	0.4
NAA	Sep 25	0.0	0.3	0 7	3 4 ±1.01	8.8
Unsprayed	———	0.0	1.2	10.8	27.3 ±2.83	—

*A concentration pf 10 ppm was used for all hormone materials.
†See footnote 2, Table 1.

Table IV gives the effect of various forms of 2,4–dichlorophenoxyacetic acids and its salts on fruit drop. It may be noted from these data that all treatments resulted in about the same high degree of effectiveness from the standpoint of fruit drop. Tree injury was much more serious, however, with the butyl ester treatment. Little, if any, difference in injury could be noted between th acid and the ammonium salt. The sodium salt appeared to result in less injury than any of the other forms tested.

TABLE IV—EFFECT OF 2,4–DICHLOROPHENOXYACETIC ACID AND SOME OF ITS SALTS ON THE HARVEST DROP OF WINESAP APPLES*

Form of 2,4-D	Average Injury Rating†	Accumulated Drop (Per Cent) October		
		14	17	22‡
NH$_4$ salt	1.8	0.2	0.2	0.3
Na salt	1 1	0.2	0.3	0.3
Butyl ester	4 1	0.2	0.2	0.2
2,4-D (acid)	2.1	0.1	0.2	0.2
Unsprayed	0 0	1 0	2.0	6.8

*All sprays were applied August 16 at a concentration of 10 ppm.
†See footnote 2, Table I.
‡Difference necessary for significance at 5 per cent point: 1.3.

DISCUSSION

These results together with those previously reported (2) clearly establish the great intensity and long duration of effect of 2,4–D in retarding the harvest drop of Winesap apples. There would seem to be a wide latitude in timing these sprays, though this chemical, within the range tested, was somewhat more effective the earlier it was applied. If these sprays are to be applied relatively early (during the month of August) either singly or in combination with a codling moth spray, precautions to eliminate the likelihood of injury must be taken. In order to avoid this injury at least two possibilities suggest themselves: (a) application of 2,4–D without the addition of oil to the spray solution. The use of oil during periods of high temperature (which usually occur during August) may result in greater absorption and penetration of the 2,4–D. The fact that no injury was obtained when oil was used in the September applications may have been due to the cooler weather prevailing following the spray applications. (b) Reducing the concentration of 2,4–D from 10 ppm to 5 ppm. In September applications (Tables I and II) the 5 ppm spray gave about the same control of drop as 10 ppm. It is reasonable to expect that this lower concentration would prove effective if applied earlier. Whether or not the 5 ppm spray can be used in August in combination with oil without producing injury remains to be determined.

The intensity of effect of 2,4–D sprays in preventing the fruit drop of Winesap apple leaves little to be desired. On many of the trees included in these experiments, drop of sound, marketable fruit was virtually eliminated. A significant reduction in "knock-offs" during the process of harvesting was noted in the 2,4–D treatments. The apples at the time of harvest were firmly attached to the spurs, yet not to the extent of making picking difficult.

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Further Results with Growth Regulators in Retarding Flower Opening of Peaches

By P. C. Marth, Leon Havis, and L. P. Batjer, *U. S. Plant Industry Station, Beltsville, Md.*

Development of a treatment that would cause a satisfactory retardation in flower opening so as to avoid spring frost injury would be of considerable value to peach as well as to many other fruit crops. The results of early investigations by Winklepeck (3) on the application of growth regulators for this purpose in early spring prior to blossoming seemed very promising. Later experiments by Mitchell and Cullinan (2) showed that treatments with growth regulators at this season may result in slightly earlier flower opening of peaches or cause considerable plant injury; and while the leaf buds may be retarded as a result of treatment, the flower buds apparently are either unaffected or injured. More recently the experiments of Hitchcock and Zimmerman (1) suggested that the time of application of the growth-regulator treatment in the case of peaches, pears, plums, cherries, and apples may best be during the preceding year at the time the flower buds of these fruits are differentiating. The results reported here are concerned with a series of field experiments on the blossom-retarding effects of growth regulators applied to Elberta peach trees at various times before and during the dormant period preceding blossom opening. The tests were carried out at Beltsville, Maryland, over a period of several years.

Experiments 1942–43

On December 24, 1942, on January 15, 1943, and on February 10, 1943, individual limbs on 11-year-old Elberta peach trees received spray mixtures containing a-naphthaleneacetic acid as well as the methyl ester of this acid. The acid was applied by means of a knapsack sprayer in spray mixtures at 300 and 600 ppm concentration in 3 per cent oil emulsion, in 3 per cent kerosene emulsion, and in 50 per cent Dowax, while the methyl ester was applied at 300 ppm concentration in each of these three carriers. A minimum of 95 per cent grain alcohol was used to dissolve the growth substance in preparing the spray mixtures. In addition, on December 24 the vapor of the ester was applied to separate limbs by sealing them over night in large 6-ply paper bags into which was introduced vapor of the ester through a short piece of glass tubing fitted to an Erlenmyer flask containing the pure compound. Approximately 100 milligrams of the ester was vaporized around the enclosed limbs by heating the flask, and thus driving the vapor into the sealed bags.

Each of the eight spray experiments as well as the vapor treatment was applied to five separate limbs selected at random on five trees, while an unsprayed limb on each tree was tagged to serve as the control. Each limb was of sufficient size to bear 30 to 40 fruits when thinned to 4 to 6 inches apart. A separate lot of five trees was used on each of the three dates of treatment.

RESULTS

A series of three frosts occurred during the blossoming period and approximately 90 per cent of the blossoms were killed in the orchard used for these tests in 1943.

Examination of the blossoms during the blossoming period failed to show any apparent protecting influence of the treatments in retarding flower opening and consequent prevention of frost injury. No injury was evident to the limbs as a result of any spray treatment used. Fruit counts were obtained on the limbs August 25, 1943. These data failed also to show any consistent frost protection effects.

EXPERIMENTS 1943–44

The experiments were continued in 1943, using water sprays containing 400 and 800 ppm concentrations of the sodium and the potassium salts of a-naphthaleneacetic acid; and Santomerse was used as a spreader in all treatments. The spray treatments were applied in late summer on the following dates: August 26, September 1, and September 13. Elberta trees in the same orchard as in the 1942 experiment were used, with essentially the same number of limbs (five per treatment) and procedure of treatment, but with the exception that a greater number of untreated limbs were tagged, so that in most instances the individual limb of any particular treatment was adjacent to an untreated limb, making possible more direct visual comparisons. In addition, on the September 13 date of spray treatment one-half of each leaf was clipped off at the midrib on a set of five comparable limbs, while on another set the entire leaves were removed. This was done to simulate mechanically the amount of leaf damage on branches sprayed on August 26.

RESULTS

Considerable leaf injury occurred on limbs sprayed with both 400 and 800 ppm of the two salts of a-naphthaleneacetic acid on August 26, as well as with the 800 ppm spray applications of September 1 and September 13 (Table I). Injury to spurs, branches, and vegetative and flower buds was severe following the August treatment but was progressively less severe with the September applications, so that the latest treatment (September 13) caused but slight or no apparent ill effects when the latest observations were made in June 1944.

Observations of flower openings were made at daily intervals in early April. Counts of the total number of flower buds and the number that were yet unopened were made on each limb of the experiment on April 8, at the time when approximately 25 per cent of the flowers had opened. These data showed no differences in flower opening between the control and any of the spray-treated limbs. Four days later (April 12) differences between the sprayed and unsprayed limbs in the number of unopened flowers they bore were apparent and blossom counts were again obtained. As shown in Table I, the percentage of unopened flowers was significantly greater on all the spray-treated limbs than on the unsprayed ones (at odds of 99: 1). The flowers on the limbs

TABLE I—EFFECTS OF APPLYING SODIUM AND POTASSIUM SALTS OF A-NAPHTHALENEACETIC ACID TO ELBERTA LIMBS IN AUGUST AND SEPTEMBER, 1943

Date of Treatment	Spray Treatment (Ppm)	Unopened Flower Buds on April 12, 1944 (Per Cent)	Injury Due to Treatment			
			Leaves	Branches	Leaf Buds	Flower Buds
Aug 26	Na* 400	42.2	++	++	++	++
	Na 800	42.0	+++	+++	+++	++
	K** 400	36.8	++	++	++	++
	K 800	50.9	+++	+++	+++	++
Sep 1	K 400	48.4	++	+	++	+
	K 800	71.6	+++	++	++	+
Sep 13	Na 400	65.7	+	0	0	0
	Na 800	63.2	++	+	+	0
	K 400	68.3	+	0	0	0
	K 800	63.3	++	+	+	+
Sep 13	†	18.6	++	0	0	0
	††	63.4	+++	0	0	0
	No Treatment	19.8	0	0	0	0

*Sodium salt of alpha-napthaleneacetic acid.
**Potassium salt of alpha-naphthaleneacetic acid.
†One-half of each leaf removed.
††All leaves removed.
0 = No apparent injury.
+ = Slight injury.
++ = Moderate injury.
+++ = Severe injury and killing.

sprayed September 1 and 13 opened significantly (99: 1) later than those sprayed August 26. No difference was shown between the two September sprays in time of flower opening. It is of interest that those limbs on which all the leaves were clipped (September 13) behaved about like the later-sprayed limbs, whereas those with one-half of each leaf clipped were similar to the controls. Following two days of rather warm weather (April 13 and 16) with temperatures about 70 degrees F at noon, the blossoms on both treated and untreated limbs opened rapidly, so that when blossom counts were made again on April 15 practically all flowers were open (less than 4 per cent unopened) on all limbs of the experiment. In these tests no differences were found between the sodium and the potassium salts of naphthaleneacetic acid in retarding flower opening or in the amount of injury that resulted.

EXPERIMENTS 1945–46

Spray treatments with the sodium salt of a-naphthaleneacetic acid were again applied in 1945 and 1946 to Elberta peach tree limbs in the orchard previously used. Similar methods were employed in spraying the limbs. A greater number of trees were used for the experiment, however, and sprays containing 200, 400, and 800 ppm of the salt were applied on August 9, August 25, September 14, September 25, October 17, November 1, 1945, and January 24, 1946. In addition to these limb experiments, whole Elberta trees (14 years old) were sprayed with 400 ppm concentrations of the sodium salt on September 25 and November 1 (Fig. 1). Nine randomized trees were sprayed on each of these dates, using approximately 8 gallons of spray per tree applied by means of a 350-gallon orchard sprayer. Nine comparable trees were left for controls.

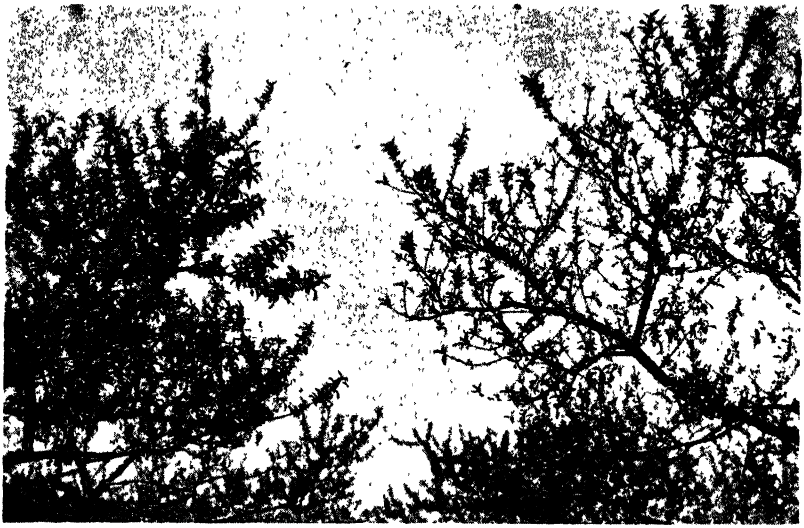

FIG. 1. Elberta peach trees. Left, no treatment; right, sprayed with 400 ppm of naphthaleneacetic acid on September 25, 1945. Photographed April 19, 1946. This spray treatment resulted in very little delay in time of flower-bud opening, but considerable delay and injury to leaf buds.

RESULTS

Counts of unopened flowers per limb were made on March 28, 1946, at the time when approximately 50 per cent of the flowers on unsprayed trees were open. The data for the percentage of unopened flowers on all limbs of the experiment are summarized in Table II. As indicated in the table, considerable variation in the percentage of unopened flowers was found among all treatments. The limbs sprayed August 25 and November 1 had significantly (99: 1) more unopened blossoms than those sprayed January 24 or the untreated ones. No further significant differences were found, even at the 19: 1 level. There were evidently no significant differences with respect to flower opening for the three concentrations of the growth substance used. Limbs sprayed during August and September with 400 and 800 ppm sprays suffered so much injury that any blossom-retarding effects would be of questionable value. Vegetative buds on these limbs were damaged or retarded in their growth so that some of the limbs appeared quite barren.

The vegetative growth on the entire trees that were sprayed on September 25 (400 ppm) likewise had fewer and smaller leaves during the early summer of 1946 (Fig. 1).

TABLE II—EFFECTS OF APPLYING THE SODIUM SALT OF A-NAPHTHALENE-ACETIC ACID TO ELBERTA LIMBS DURING THE FALL AND WINTER OF 1945–46

Date of Treatment	Spray treatment (Ppm)	Unopened Flower Buds on Mar 28, 1946 (Per Cent)	Injury Due to Treatments			
			Leaves	Branches	Leaf Buds	Flower Buds
Aug 9	200	46.5	++	++	++	+
	400	All dead	+++	+++	+++	+++
	800	All dead	+++	+++	+++	+++
Aug 25	200	69.2	++	++	++	+
	400	55.6	++	++	++	++
	800	57.9	++	++	++	++
Sep 14	200	49.9	++	+	++	+
	400	45.2	++	++	++	+
	800	57.6	+++	++	++	+
Sep 25	200	49.7	+	+	+	0
	400	46.3	++	+	+	0
	800	56.9	++	++	++	+
Oct 17	200	49.8	+	0	+	0
	400	54.8	+	0	++	0
	800	52.7	++	+	++	+
Nov 1	200	56.5	0	0	+	0
	400	58.8	0	0	++	0
	800	65.1	0	0	++	0
Jan 24	200	37.3	0	0	+	0
	400	48.6	0	0	+	0
	800	39.7	0	0	++	0
	No treatment	43.7	0	0	0	0

0 = No apparent injury
+ = Slight injury
+ + = Moderate injury.
+ + + = Severe injury or killing.

DISCUSSION AND SUMMARY

Although a slight retarding effect on the opening of flower buds of Elberta peaches was found from spray applications of the sodium or the potassium salt of naphthaleneacetic acid when applied in August, September, and October of the preceding year, the delay in flower opening in the succeeding spring was of short duration. In the best results opening was delayed approximately 2 days. In no case did the length of delay approach the results reported by Hitchcock and Zimmerman (1). Furthermore, the delay was associated with moderate to severe injury to leaves and leaf buds as well as often to the flowers and branches. The growth of vegetative buds was moderately to severely retarded on the individual branches or whole trees that were sprayed. Sprays applied during August caused branch killing at 800 ppm spray concentration, and moderate to severe damage at 200 and 400 ppm concentration. In these experiments retardation effects were not obtained without injury to the leaves. In fact, the retardation of flower opening obtained in these tests may have been due to the reduction in foliage resulting from the phytotoxic effect of the spray. It is of interest that in one of the experiments, clipping off the entire leaf area by mechanical means in mid-September caused a slight retarding effect similar to that obtained from sprays applied at this time. The fact that some retarding effects were noted in the course of these experiments is a hopeful sign that perhaps with further work in this field other chemicals or methods of applying them will be uncovered which will be more specific in action on flower buds and less injurious to the vegetative parts of the plant. Because of the leaf, bud, and twig injury associated with the use of these materials, we feel that they should not yet be recommended for commercial orchard trials by fruit growers.

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Studies in Peach Thinning

By Leon Havis, *U. S. Plant Industry Station, Beltsville, Md.*

The recent desire for more information on labor-saving methods of peach thinning has resulted in several studies and reports on the subject. The use of Elgetol for peach blossom thinning has been of special interest (1, 2, 3). When the work reported here was started in the spring of 1944 it seemed particularly desirable to determine the most satisfactory time of application of Elgetol and the concentration, as well as the interaction of these two factors; also to determine the effects of time of application and concentration of Elgetol at different levels of tree vigor.

Twelve-year-old Elberta peach trees at Beltsville were used for the thinning tests. The treatments were randomized and included 10 vigorous and 10 weak trees per treatment in 1944. The "weak" trees were those in bluegrass sod, in contrast to the "vigorous" trees under cultivation. The test in 1946 included only the 10 vigorous trees in each treatment. In addition to the Elgetol, the wire-brush method of thinning (4) was included in these tests. Since neither the wire brush nor the Elgetol thins the peach blossoms uniformly over the tree, the value of uniform thinning in bloom was tested by including a hand-thinning treatment. June hand-thinning and no-thinning treatments were used as standards or controls for comparison. Unfortunately, the June-thinned trees were overthinned, so that the results were of limited value for comparison.

In 1944 there was a full crop of peaches, with no killing of blossoms or young fruits by low temperatures in the spring, and only a moderate June drop. In 1945 most of the young fruits were destroyed by low spring temperatures, therefore no results were obtained. In 1946 there was little cold damage to fruits in this test, but there was an extraordinarily heavy June drop. Since the most reliable results were obtained in 1944, they are presented in most detail here.

The yield of fruit in 1944 in all treatments was greater for the vigorous trees (Table I). The differences between treatments were not significantly affected by the tree vigor, however. The analysis of variance for the yield results, without regard to tree vigor, showed that at the 99: 1 level of significance:

1. Treatment No. 12 (June thinning) yielded less than all the other treatments, except Nos. 8, 9, and 11.
2. Treatment No. 9 (1½ pints of Elgetol per 100 gallons, 4 days after full bloom) yielded less than all other treatments except No. 12, and less here at odds of 19: 1.

The low yield of the June-thinned treatment was undoubtedly due largely to the fewer fruits on these trees, but the extent of yield reduction due to late thinning was not clear. The low yield of treatment No. 9 was, of course, due to the severity of the blossom thinning (Table I). The other differences between yields of treatments were not found to be statistically significant. Considering the concentration of the spray alone, the Elgetol at 1½ pints per 100 gallons resulted in the lowest yields; and considering the time of application alone, the one 4 days

TABLE I—EFFECTS OF ELBERTA PEACH THINNING TREATMENTS IN 1944 ON YIELD, SIZE, AND NUMBER OF FRUITS PER TREE (BELTSVILLE, MARYLAND)

Plot No.	Treatments	Yield (Bushels)		Size (Number Per Bushel)		Number Fruits Per Tree	
		Weak Trees	Vigorous Trees	Weak Trees	Vigorous Trees	Weak Trees	Vigorous Trees
1	½ pint Elgetol per 100 gallons when 55 per cent blossoms open	7.7	8.8	183	209	1,420	1,840
2	1 pint Elgetol per 100 gallons when 55 per cent blossoms open	6.8	7.9	188	207	1,237	1,643
3	1½ pints Elgetol per 100 gallons when 55 per cent blossoms open	6.9	9.3	169	198	1,174	1,837
4	½ pint Elgetol per 100 gallons at full bloom	6.8	9.1	186	207	1,266	1,882
5	1 pint Elgetol per 100 gallons at full bloom	7.2	8.7	164	218	1,171	1,870
6	1½ pints Elgetol per 100 gallons at full bloom	6.8	8.9	142	163	972	1,443
7	½ pint Elgetol per 100 gallons 4 days after full bloom	7.2	8.9	170	205	1,223	1,824
8	1 pint Elgetol per 100 gallons 4 days after full bloom	6.1	8.7	140	163	855	1,434
9	1½ pints Elgetol per 100 gallons at 4 days after full bloom	3.1	4.6	106	118	328	534
10	Wire brush at full bloom	6.5	8.9	171	179	1,109	1,591
11	Hand thinning of blossoms at full bloom	5.9	7.8	139	149	819	1,140
12	Hand thinning June 13 and 14	4.9	6.3	155	167	755	1,060
13	No thinning	6.3	8.5	184	216	1,155	1,837

after full bloom resulted in significantly lowest yields. None of the other differences in yields were statistically significant.

The relative fruit size in the different thinning treatments was measured by determining the number of fruits per bushel (Table I). On this basis, considering vigorous and weak trees together, the significant (99: 1) results by treatments were:

Treatment No. 9 produced larger fruits than any other experiment except No. 11, and even here at odds of 19: 1.

Treatment No. 6 produced larger fruits than Nos. 1, 2, 4, 5, 7, and 13.

Treatment No. 11 produced larger fruits than Nos. 1, 2, 3, 4, 5, 7, and 13.

Treatment No. 8 produced larger fruits than Nos. 1, 2, 4, 5, 7, and 13.

Treatment No. 12 produced larger fruits than Nos. 1, 2, 4, and 13.

Fruit size was so closely associated with the severity of thinning that any relationship to uniformity of fruit distribution on the tree and to time of thinning was obscure. The fruit size was significantly greater and the number of fruits per tree was significantly smaller as the spray concentration was increased. The size of fruit was greater with the later sprays, probably because more thinning was obtained. The weak trees produced larger peaches than the vigorous trees, probably because of the greater June drop from the weak ones and not because of thinning treatments. The interaction of concentration of Elgetol and vigor of trees resulted in no significant differences in the mean size of peaches. The interaction of time and concentration indicated definitely larger sizes with stronger concentrations at the later dates of application. There was an interaction of Elgetol concentration and time of application, which resulted in the largest fruit from the higher concentrations, and at the later applications.

The number of fruits per tree was determined at harvest by counting all of the peaches borne by each tree. Both the treatment and the tree vigor significantly affected the set or number of fruits per tree. The vigorous trees bore an average of 1,528 peaches per tree, whereas the weak trees produced 1,030 peaches per tree. The trees in treatment No. 9 (1½ pints of Elgetol, applied 4 days after full bloom) were thinned more (odds of 99:1) than in any other treatment; whereas treatments Nos. 11 and 12 (hand thinning at full bloom and in June) were thinned more than any other except Nos. 6 and 8. Considering spray concentration alone, the amount of thinning obtained increased directly with the concentration of the Elgetol. Considering the time of spray application, it was found that the spray applied 4 days after bloom resulted in a significantly (99: 1) lower number of fruits than the other two times of application; the difference between the first and second applications was not significant at that level. The vigorous trees produced a significantly larger number of fruits per tree than the weak ones. The most effective thinning was by the most concentrated Elgetol and on the later date of application. The weak trees set a lighter crop, but this was evidently due little or not at all to the Elgetol, since other thinning treatments and no thinning also set about equally less on weak trees (Table I).

In 1946 there was an extremely heavy June drop of fruits in all treatments. Since much of the peach drop resulting from Elgetol occurs during the early part of this period, the relative amount of thinning by Elgetol treatments could not be determined. All trees dropped their fruits so much that there was no significant difference between the number, sizes, or yields in any treatment. Although the results in 1946 are not at all typical, it is noteworthy that they may occur. The average yield in 1946 was 6.46 bushels per tree, and the peaches averaged 2½ inches in diameter.

The results presented here indicate that in a "normal" year Elgetol applied at ½, 1, or 1½ pints per 100 gallons before full bloom, and at ½ or 1 pint per 100 gallons at full bloom failed to significantly thin the Elberta peaches; also that 1½ pints at full bloom and 1 pint 4 days later thinned the fruit to the extent that the size on vigorous trees was increased from approximately 2⅛ inches (no thinning) to approximately 2⅜ inches without affecting the yields per tree. The wire brush also seemed to result in about the same increase of size without reduction in yield. The concentration of 1½ pints at 4 days after full bloom thinned too severely. Although thinning peaches with phytotoxic sprays may be of value in areas that are relatively free from frost, the results seem to vary considerably from year to year.

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Observed Residual Effects on Apples of 2,4–D in a Central Spray System[1]

By Ray S. Marsh and Carlton F. Taylor, *West Virginia University, Morgantown, W. Va.*

While making some orchard visits on June 6, 1946, the authors' attention was called to a block of severely injured trees where 2,4–D, (2,4–dichlorophenoxyacetic acid — Weedone, a proprietary form,) had been used on August 22, 1945 as an eradicant spray for poison ivy (*Rhus Toxicodendron* L.). A stationary spray system was used for applying the 2,4–D at low pressures to the ivy foliage under the trees. Following this application the spray pump and pipe lines were rinsed with water until all traces of odor and visible evidence of the 2,4–D residue was removed. One week later an oil spray (6 quarts summer oil in 100 gallons water) was applied through this spray system to control orchard mites.

The orchard operator failed to notice any unusual conditions until fall. Then it was observed that both the fruit and foliage in this Winesap and Stayman block adhered tenaciously to the trees. Through the winter the foliage hung on these trees "dry and brown like the leaves on Shingle oaks", according to the orchard manager. In 1946 the blossoming of this Winesap and Stayman block was 7 to 10 days later than that of the same varieties in other parts of the orchard.

On June 7 the first photographs were made to supplement the observations made the previous day. In addition to the narrowed, deeply-

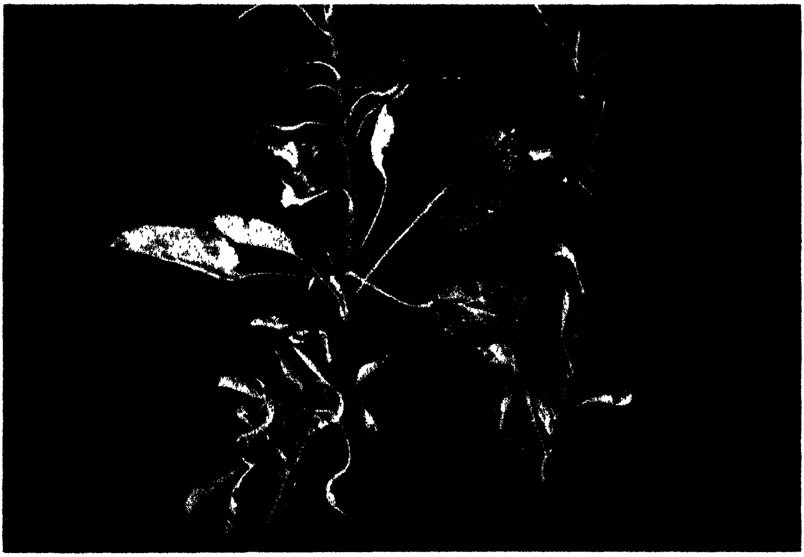

Fig. 1. Malformed foliage, June 7, 1946.

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[1] Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 364.

serrated, epinastic, and frequently mottled leaves and the impression of a very low amount of total foliage area, the adherence of undeveloped, dried apple blossom parts was very noticeable. Also the damage, to the current crop on this block of about 300 trees, was estimated at between four and five thousand dollars. Because of foliage conditions, it was believed that the few apples set would be small (at harvest, the small crop of apples produced was reported to be prematurely ripened and not suitable for storage). Trees of Winesap, Stayman, and Northern Spy (one tree) were severely damaged. Little or no injury was observed on interplanted York, Gano, and Turley (one tree) or on Black Twig in a separate block similarly treated. Here and there through the orchard a single limb of Delicious and Grimes was observed to have suffered some damage. At first it appeared that the injury from 2,4-D was more severe on triploid varieties but further observations indicated there was no correlation.

FIG 2 Development of foliage of normal appearance, September 10, 1946.

Several visits were made to this injured block of fruit trees during the 1946 season and additional photographs were taken in early September. As early as mid-August it was evident that the trees were making some recovery. This was indicated by the more normal foliage development on the tips of terminal growths. However, this recovery was not sufficient to predict a fully normal tree condition for the season of 1947.

It is considered possible that the summer oil acted as a solvent of 2,4-D residual in the spray lines and also enhanced its effect by accelerating its penetration into the tissues of the tree. Since several thousand gallons of oil-spray material were passed through a single

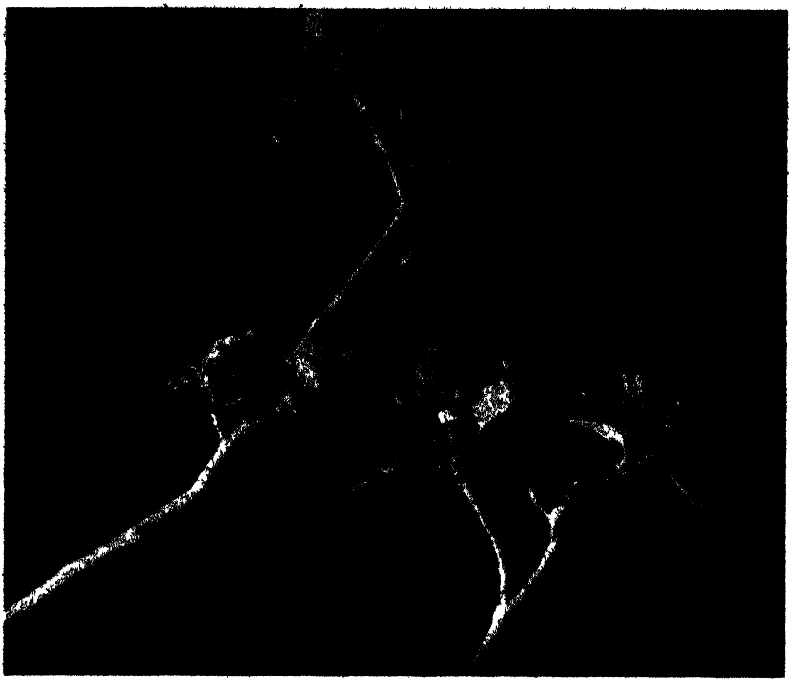

FIG. 3. Dwarfed foliage and retained parts of undeveloped blossoms, June 7, 1946.

FIG. 4. Fruit development in relation to reduced foliage. Parts of undeveloped blossoms still present, September 10, 1946.

spray line, and the tree injury was as pronounced on those sprayed last as it was on the trees at the head of the line, the dilution of 2,4–D must have been too great to have caused such damage without the penetrating action of the oil.

In conclusion, the severe damage caused by the 2,4–D adds further evidence to observations which have been made by other workers, such as (a) the exaggerated effect as a pre-harvest spray on undeveloped blossom parts, leaves and fruit; (b) its hormone effect as a spray for delaying blossoming in the spring; (c) the selective action of 2,4–D for Winesap, Stayman, and possibly Northern Spy; and (d) the lasting quality of this chemical in its effects on plant reaction (the effect was pronounced through a 10-month period). From these observations, it may be possible that the cumulative effect of 2,4–D used annually over a period of years, at even the dilute solution recommended for pre-harvest use, may result in tree injury.

Bindweed Control Studies With 2,4–D in a Bearing Non-Irrigated Orchard in Eastern Washington[1]

By L. R. BRYANT, C. L. VINCENT, and E. G. SCHAFER, *Washington Agricultural Experiment Station, Pullman, Wash.*

BINDWEED has continued to be one of the most serious weed pests in cultivated fields and in orchards in eastern and central Washington. A study of methods of eradication for the most part have been conducted on land utilized for field crops. To better meet the bindweed control problem with orchard crops, a study on the control of bindweed in a bearing, non-irrigated orchard was initiated in the spring of 1945. Attempts at bindweed control by the use of chemicals had been made previously by individuals in the various fruit growing districts of Washington but no extensive program had been undertaken because of possible injury to trees from chemicals commonly used to eradicate the weed.

METHODS

A small apple orchard at the Main Station of the Washington Experiment Station at Pullman, Washington, seriously infested with bindweed, was laid out in plots 30 by 30 feet in size with a bearing apple tree in the center of the plot area. Most of the treatments were made at two concentrations and some were at two different dates. In all, 15 different chemicals were used.

Where 2,4–dichlorophenoxyacetic acid, 2,4–D, or its derivations, were used, the concentrations were at the rate of 1000, 1500 or 2000 parts per million of 2,4–D. Sodium chlorate was applied as a spray at the rate of 2 ounces and 4 ounces, and paint thinner at ¾ gallon and 1 gallon per square rod.

Spray applications were made with small wheelbarrow hand and power sprayers using pressures between 50 and 75 pounds. The nozzle used had a 0.059 inch opening which gave a medium fine, fan-shaped spray. The sprays were applied across the plots in one direction and then across in the opposite direction to assure adequate coverage.

The work was continued and expanded in 1946 with some treatments being eliminated. Sodium chlorate treatments and top killers, such as paint thinner, were discarded in 1946 because they were not effective at the light application that could be used without injury to the trees. Some commercial experimental materials used in 1945 were not available in 1946 and, wherever possible, these were replaced with similar formulations. A number of commercial products, all based on 2,4–D, were added, bringing the total number of treatments for 1946 up to 71. Concentrations of these ranged from 500 to 2,000 parts per million of actual 2,4–D.

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[1] Published as Scientific Paper No. 700, College of Agriculture and Agricultural Experiment Stations.

The authors are indebted to Dr. George W. Fischer for photography and to Mr. C. I. Seely and Dr. W. B. Fox for assistance in field work.

RESULTS

Most of the materials applied on July 10, 1945 gave a good kill of bindweed tops although some of the plots, where a good top-kill had been obtained, showed heavy regrowth by June 19, 1946. Regrowth and stands following the use of sodium chlorate and paint thinner were very heavy. Best control was obtained from materials containing 2,4–D. All of these applications resulted in an appreciable reduction in stand of plants in 1945 but in 1946 bindweed stands in these plots, by count, varied from one to 25 per cent as compared to the checks. Application of materials made on July 31, 1945 were less effective than the earlier applications. The best of the limited number of chemicals used in the trials laid out in 1945 were the materials containing actual 2,4–dichlorophenoxacetic acid. Top kill resulting from commercial materials used in 1946 was most striking with those containing the methyl ester, the alkanolamine salt, the butyl ester, and the triethanol amine salt of 2,4–D at concentrations of 1,500 and 2,000 parts per million. Root kill of the bindweed, where these had been used, was heavy.

The new plots were treated during the second week in June and since it had become evident that a single treatment in any given year would not give satisfactory control of bindweed in orchards, retreatments of the 1945 plots were made during the third week in June, 1946. All plots were given another treatment the fourth week in July.

In 1946, a lower limb of the tree in some of the plots was sprayed thoroughly with the 2,4–D material used on the bindweed to determine the effect of the materials on apple wood and leaves. Observations made on August 2, 1946, on the trees on which branches had been sprayed, gave no evidence that the 2,4–D sprays had affected any part of the trees except the sprayed branches. Young leaves to which 2,4–D had actually been applied were somewhat twisted and deformed but later in the season the new growth on the same branches above the affected areas appeared normal. Materials, which contained top killers in addition to the 2,4–D, had burned the foliage severely. Many of these injured leaves had dropped and some of the limbs showed bark injury. There appeared to be varietal differences in tolerance or resistance to these materials, Stayman being more sensitive than Jonathan, McIntosh, or Delicious.

Fruits from this orchard harvested in 1946 showed a rather large number of abnormalities that appear to have resulted from applications of 2,4–D made to the bindweed in 1945. Some of the fruits showed only rudimentary or no seed development. McIntosh apples, normally round-oblate, had become oblong in shape with the core even more open than normal as shown in Fig. 1, while the Jonathan had changed from round-conic to oblong-conic, Fig. 2. A considerable number of Jonathan and Delicious apples were doubles as shown in Figs. 3 and 4. These malformations may have come from the 2,4–D being translocated through the roots of the trees, from the material drifting at the time the bindweed was sprayed, or from volatile materials in the spray itself.

FIG. 1. Fruit from plot sprayed with 2,4-D. McIntosh fruits showing elongation and extremely open cores.

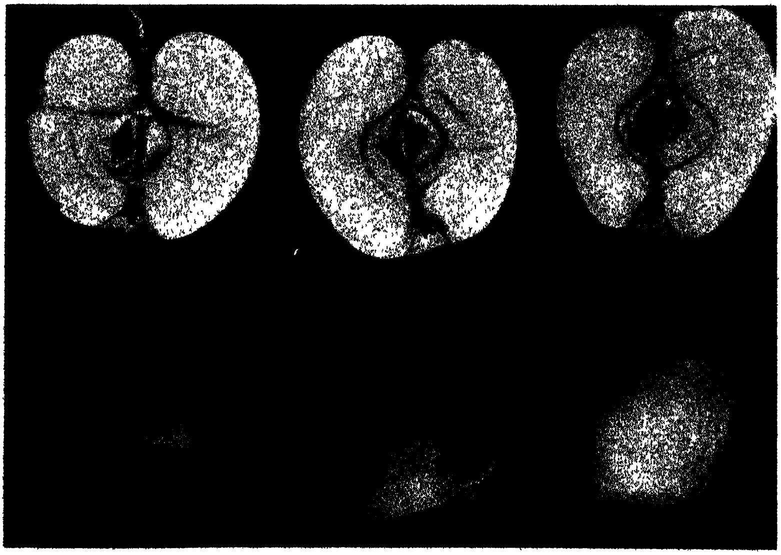

FIG. 2. Fruit from plot sprayed with 2,4-D. Jonathan, left, showing normally shaped fruit; center and right, elongated fruits.

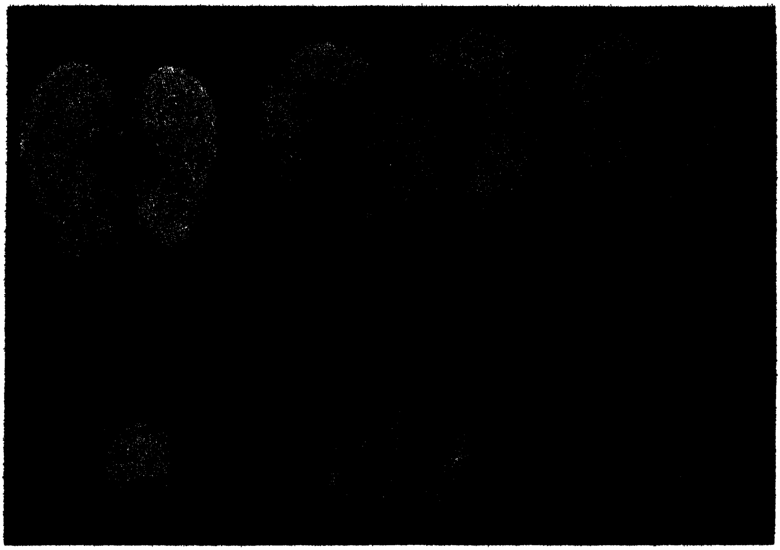

FIG 3 Fruit from plot sprayed with 2,4-D Delicious, left showing normal fruit; center and right, two types of abnormal fruits

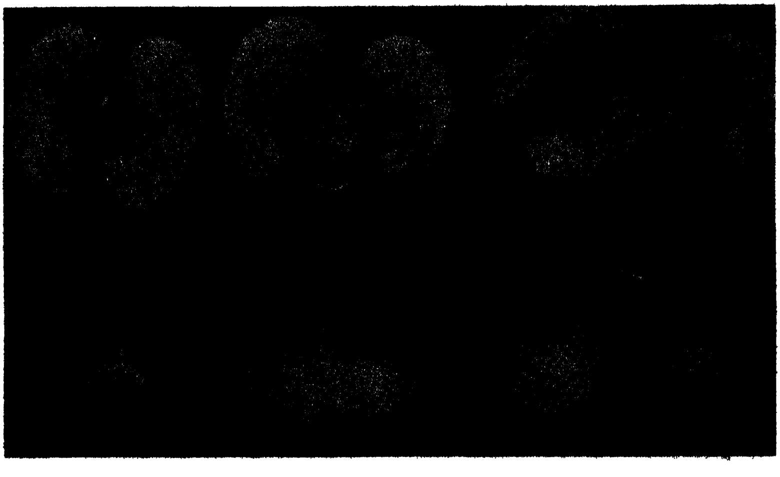

FIG. 4. Fruits from plot sprayed with 2,4-D. Jonathan, left, normal fruit; center, "doubled" fruit with fasciated calyces; right, doubled fruits with separated calyces.

The work will be continued in 1947 with greater emphasis being placed on malformation of fruit and its development and position in the trees as related to the weed control sprays used.

The Effect of Some Hormone Materials on the Respiration and Softening Rates of Apples

By R. M. Smock and C. R. Gross, *Cornell University, Ithaca, N. Y.*

The use of certain "hormone" materials for apples has been suggested for a number of purposes. Foremost among these has been the use of substances like a-naphthaleneacetic acid for the prevention of fruit abscission during the normal harvesting period. It is well recognized that fruit sprayed with this material should not be allowed to hang on the tree so long that it will become over-mature (4). In the earlier studies on the possibility of any *direct* effect on fruit ripening it had been concluded that such sprays did not directly stimulate ripening (2, 4). More recently the possibility of a direct ripening effect of a-naphthaleneacetic acid sprays on the ripening of apples and pears has been reported (3, 1).

Another purpose for which hormone dips or sprays have been suggested is in accelerating the ripening of certain fruits. Dipping of apples in 2,4-dichlorophenoxyacetic acid has been shown to be effective in stimulating the ripening rate (5). The ripening of green peaches can be stimulated by the use of dusts containing the methyl and ethyl esters of naphthaleneacetic acid (8). One study has reported that weak concentrations of indoleacetic acid in maize oil would stimulate the ripening rate of pears but that strong concentrations would retard it (6). With citrus it has been found that weak concentrations of materials like naphthaleneacetic acid, indolebutyric acid, and indoleacetic acid in lanolin pastes checked ripening, but high concentrations stimulated it (9).

A third purpose for which hormone materials has been suggested is the control of apple scald. Schomer and Marth (7) have reported reductions in storage scald with dipping treatments of naphthaleneacetic acid in lanolin emulsion.

The purpose of this investigation was to study the effects of spraying apples before harvest and dipping them after harvest with some of these hormone materials.

METHODS

Individual, large limbs of apple trees were sprayed with the various hormone materials. Apples for comparative purposes were taken from untreated limbs of the same trees in all cases but one (McIntosh, 1944). During the 1945 season, fruits sampled from the untreated limbs were taped on to the tree to prevent falling. This practice was not continued since it did not prevent abscission even though the apples did not actually drop.

When fruit "dip" treatments were made, the fruits were immersed in the hormone materials for only a few seconds.

Respiration measurements were started 24 hours after harvesting of the fruit on approximately 4 kilogram samples. These measurements were made by absorbing the evolved carbon dioxide in .3N sodium hydroxide, precipitation of the carbonate with barium chloride, followed by titration with standard strength hydrochloric acid.

Firmness measurements were made with a Magness-Taylor pressure tester on 20 fruits per sample.

1941 RESULTS

McIntosh:—On September 3, 1941 one large limb of McIntosh apples was sprayed with 10 parts per million of a-naphthaleneacetic acid. Normal abscission was just starting at that date. Samples of apples were taken for respiration measurements on September 17, 24, and on October 1. The data are not presented because no differences in respiration rate between sprayed and unsprayed fruits could be observed.

1944 RESULTS

McIntosh:—On September 20, 1944 one large limb of McIntosh apples was sprayed with 10 parts per million of a-naphthaleneacetic acid. Normal abscission was just starting on that date. Samples of apples were harvested on September 22, 25, 29, and October 6. The respiration results appear in Fig. 1. With the first and second picking there was a suggestion of increased respiratory rate as a result of spraying. By the third picking a marked stimulation in respiration rate had resulted. With the fourth picking no differences were noted; both sprayed and unsprayed apples being post-climacteric at this time.

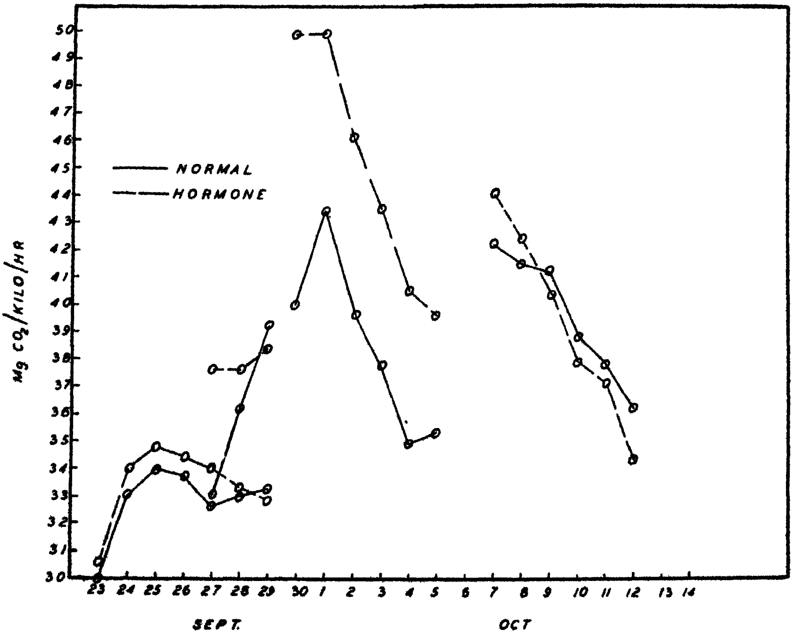

FIG. 1. Effect of limb spray of 10 ppm a-naphthalene acetic acid on respiration of McIntosh at 74 degrees F. Sprayed September 22, 1944; harvested September 22, 25, 29 and October 6, 1944.

1945 Results

Duchess of Oldenburg:—On August 11, 1945 one large limb of Duchess apples was sprayed with 25 parts per million of a-naphthaleneacetic acid. Normal abscission did not start for several days after this date. Samples of apples were harvested for respiration measurements on August 13 and 20. Fruits harvested at both dates showed accelerated respiration rates as a result of the spray treatment (Fig. 2).

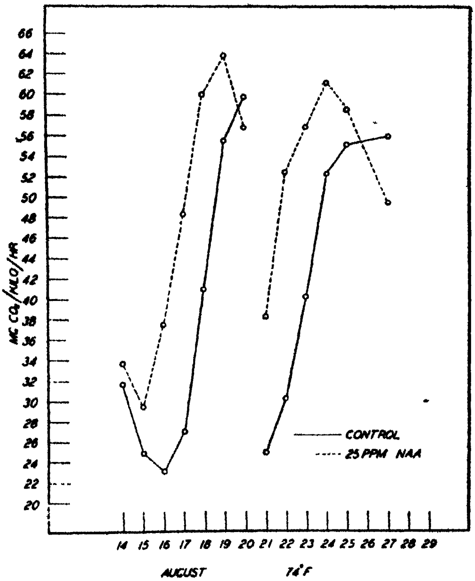

Fig. 2. Effect of limb spray of a-naphthalene acetic acid on respiration of Duchess at 74 degrees F. Sprayed August 11, 1945; harvested August 13 and 20, 1945.

Sprayed fruits from the first picking softened 1.1 pounds more during the 7 day holding period at 74 degrees F than the control. Sprayed fruits at the second harvest date were 1.5 pounds softer than unsprayed fruit, and softened .3 pounds more than the latter during the 7 day holding period at 74 degrees F.

Wealthy:—On August 30, 1945 one large limb of Wealthy apples was sprayed with 12.5 parts per million of a-naphthaleneacetic acid. A second large limb was sprayed with the same concentration of the hormone material but .5 per cent Carbowax (1500 W) was included in the spray. Natural abscission was just starting at this time. The fruits were harvested on September 3. One series was held at 74 degrees F and a second series at 33 degrees F. After the second series had been held at 33 degrees F for 49 days, it was removed to 74 degrees F and held for an additional period of 9 days.

The results are not presented. The fruits which had been sprayed with hormone only showed an increased respiration rate during the 7 day holding period at 74 degrees F following harvest. Fruits sprayed with hormone plus Carbowax did not show this increase. During the storage period at 33 degrees F no significant differences in respiration could be noted. When the apples were removed from cold storage and stored at 74 degrees F, there was some indication of faster respiration with the hormone plus Carbowax sprayed fruit.

During the 7 day holding period at 74 degrees F following harvest the hormone-sprayed apples softened 1.0 pound more than the unsprayed fruits. The Carbowax plus hormone sprayed fruit softened the same amount as the unsprayed fruit. During 33 degrees F storage, all three lots of apples softened at the same rate.

McIntosh:—A large limb of McIntosh apples was sprayed with 12.5 parts per million of a-naphthaleneacetic acid plus .5 per cent Carbowax (1500 W) on September 25, 1945. Natural abscission was just starting at this date. On September 29th the apples were harvested and one lot of unsprayed fruit was dipped in .5 per cent Carbowax and another lot was dipped in .5 per cent Carbowax plus 12.5 parts per million of a-naphthaleneacetic acid.

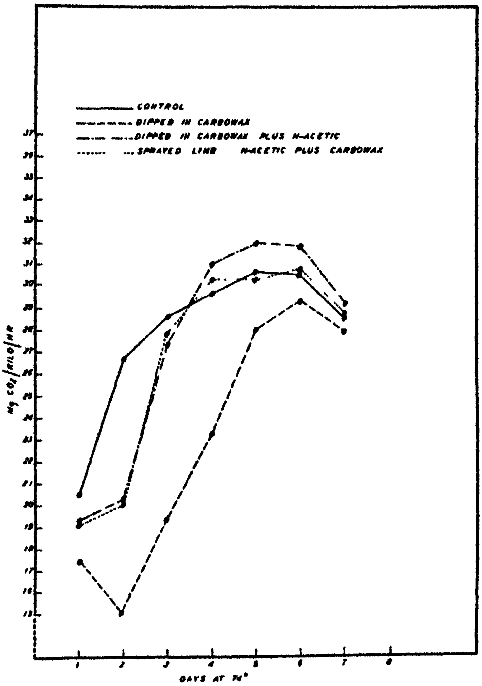

FIG. 3. Effect of limb sprays and post harvest dip treatments with 12.5 ppm a-naphthaleneacetic acid and .5 per cent Carbowax as indicated on legends on respiration of McIntosh at 74 degrees F. Sprayed September 25, 1945; harvested and dip treatments made September 29, 1945.

The respiration results (Fig. 3) indicate that the hormone plus Carbowax spray treatment did not significantly affect the respiration rate. The Carbowax dip treatment resulted in a significant reduction in respiration rate. The Carbowax plus hormone dip treatment did not differ markedly from that of the control, although the rate of respiration was greater than that with the Carbowax alone.

None of these treatments except the Carbowax dip treatment had any effect on the rate of softening of these apples during the 7 day holding period at 74 degrees F. The Carbowax dip fruits were .4 pounds firmer than the other lots.

1946 RESULTS

Duchess of Oldenburg:—On August 9, 1946 two large limbs of Duchess were sprayed with 30 parts per million of the sodium salt of a-naphthaleneacetic acid. One picking of fruit was made on August 13 and a second picking on August 19 from sprayed and unsprayed limbs. On August 19, another unsprayed limb of this tree was sprayed with the same concentration used previously. Fruit was harvested from this later-sprayed limb and from unsprayed limbs on August 22. Active normal abscission had started on this tree about August 18.

The results in Fig. 4 show that the hormone spray of the first application date stimulated the respiration rate of the Duchess apples at both picking dates. The application at the later date had a similar stimulating effect on respiration rate.

The sprayed fruits from the first picking of the first spray softened .9 pounds more during the 10 days holding period at 74 degrees F. than the controls. Sprayed fruits from the second picking of the first spray softened 1.4 pounds more during the 8 day holding period at 74 degrees F than the controls. Sprayed fruits from the later spray treatment softened 1.4 pounds more than the controls during the 6 day holding period at 74 degrees F.

Wealthy—Experiment A: — Since it has been reported that dipping fruit in a lanolin emulsion of a-naphthaleneacetic acid reduced storage scald (7), the effect of this treatment on respiration rate of Wealthy apples was examined. Preclimacteric Wealthy apples were dipped in lanolin emulsions containing 30 and 500 parts per million of a-naphthaleneacetic acid. Apples were also dipped

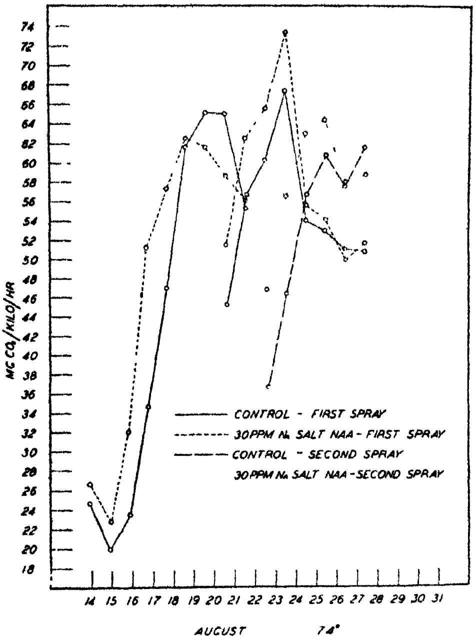

FIG. 4

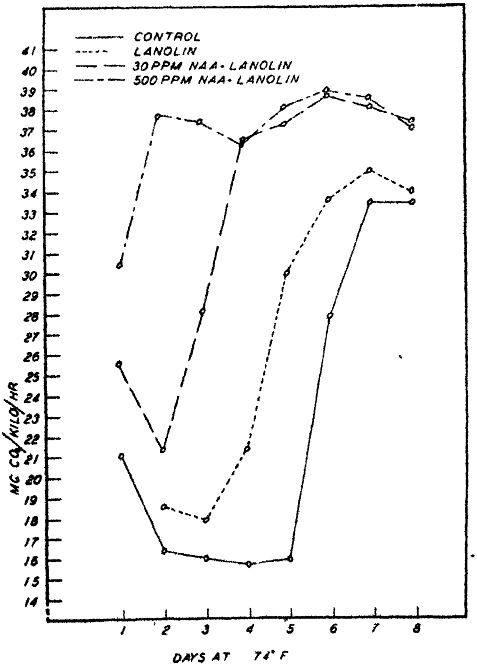

FIG. 5

FIG. 4. Effect of limb sprays of 30 ppm of a-naphthalene acetic acid on respiration of Duchess at 74 degrees F. Sprayed August 9 and 18, 1946. First spray harvested August 13 and 19, 1946; second spray harvested August 22, 1946.

FIG. 5. Effect of lanolin and a-naphthalene acetic acid in lanolin (dip treatments) on respiration of Wealthy apples at 74 degrees F.

in the lanolin emulsion alone. The emulsions were prepared as described by Schomer and Marth (7) except that trimethylamine was used instead of trimethanolamine.

The results in Fig. 5 show that the emulsion alone caused some respiratory increase. Thirty parts per million of the hormone in lanolin resulted in a marked respiratory increase, and 500 parts per million in lanolin in a still greater increase.

The apples dipped in the emulsion only softened .5 pounds more during the 8 day holding period at 74 degrees F than the control. Those dipped in 30 parts per million of the hormone in lanolin were .9 pounds softer than the control at the end of this period. Those dipped in 500 parts per million of hormone in lanolin were 1.9 pounds softer than the control at the end of 8 days.

Wealthy—Experiment B:—In this experiment spray treatments were made on individual limbs of a Wealthy tree on August 27, 1946. Fruits were harvested for respiration measurements on August 30 and September 6. One limb was sprayed with 20 parts per million of sodium salt of a-naphthaleneacetic acid. A second limb was given the same concentration of hormone plus .5 per cent Carbowax (1500 W). A third limb was sprayed with 20 parts per million of 2,4-dichlorophenoxyacetic acid plus .5 per cent Carbowax. One series of apples from these treatments and the control limb (at the first picking) were held at 74 degrees F, and another series (except for the 2,4-D treatment) was held at 33 degrees F. The second picking was held only at 74 degrees F. Normal abscission started on about September 6.

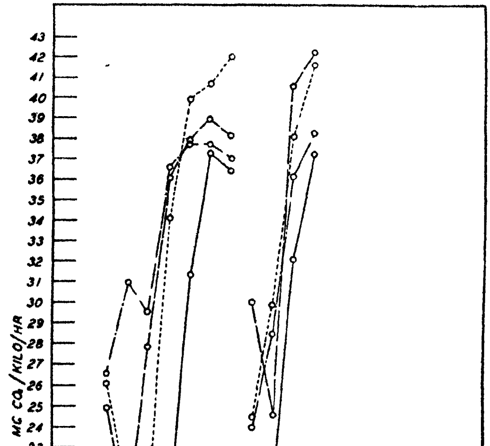

FIG. 6. Effect of limb sprays of sodium salt of a-naphthalene acetic acid with and without Carbowax and 2,4-D on Wealthy apples at 74 degrees F. Sprayed August 27, 1946; harvested August 30 and September 6, 1946.

Fig. 6 includes the respiration data of the fruit held at 74 degrees F. It is apparent that all spray treatments stimulated the respiration rate of these apples. Differences between the various sprays are not clear cut. Unlike the previous year's results with hormone plus Carbowax, the addition of the latter did not seem to reduce the stimulatory effect of the hormone.

During the 7-day holding period at 74 degrees F the first-picked fruit sprayed with 20 parts per million of the sodium salt of a-naphthaleneacetic acid softened .7 pounds more than the control. The sodium salt of a-naphthaleneacetic acid plus Carbowax sprayed fruit softened 1.8 pounds more than the control and the 2,4-D fruit softened 1.3 pounds more than the control.

At the time of the second picking pressure tests were made on the fruit from the various treated limbs. These differences would indicate changes that had taken place on the tree during the 10 days after spraying. Both the sodium salt of a-naphthaleneacetic acid spray and

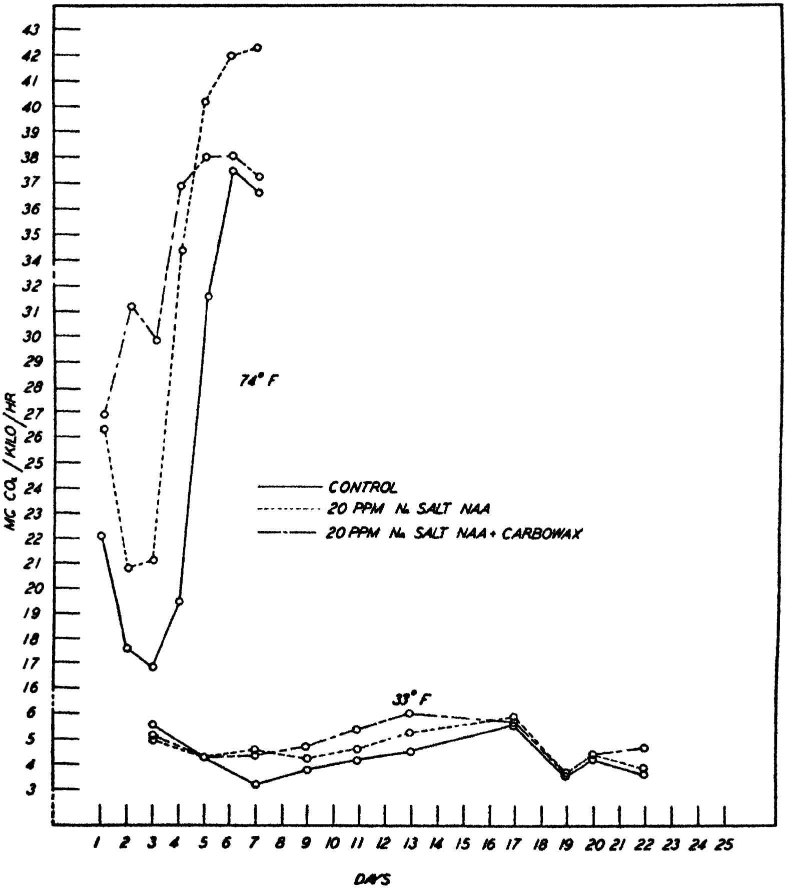

FIG. 7. Effect of limb sprays of sodium salt of a-napthalene acetic acid with and without Carbowax on Wealthy apples at 74 degrees and 33 degrees F. Sprayed August 27, 1946; harvested August 30, 1946.

the sodium salt with Carbowax resulted in .9 pounds more softening than the control and the 2,4-D fruit was 1.6 pounds softer than the control.

Respiration at 33 degrees F was so slow that the differences of individual analyses (Fig. 7) were small. Averaged over a 20-day period, the unsprayed fruit respired at the average rate of 4.56 milligrams CO_2/kg/hr, while the hormone-sprayed fruit, and the fruit sprayed with hormone plus Carbowax respired at the slightly faster average rates of 4.93 and 5.25 milligrams respectively. Pressure tests further indicated the positive effect of the hormone on respiration. During the period of 22 days at 33 degrees F, the fruits sprayed with the hormone alone softened 1.3 pounds more than the control. Those sprayed with hormone plus Carbowax softened 1.0 pounds more than the control.

Wealthy—Experiment C:—Individual limbs of a Wealthy tree were sprayed on September 2, 1946 with 10, 20, and 30 parts per million of the sodium salt of a-naphthaleneacetic acid. Another limb was sprayed on September 2 with 20 parts per million of this material

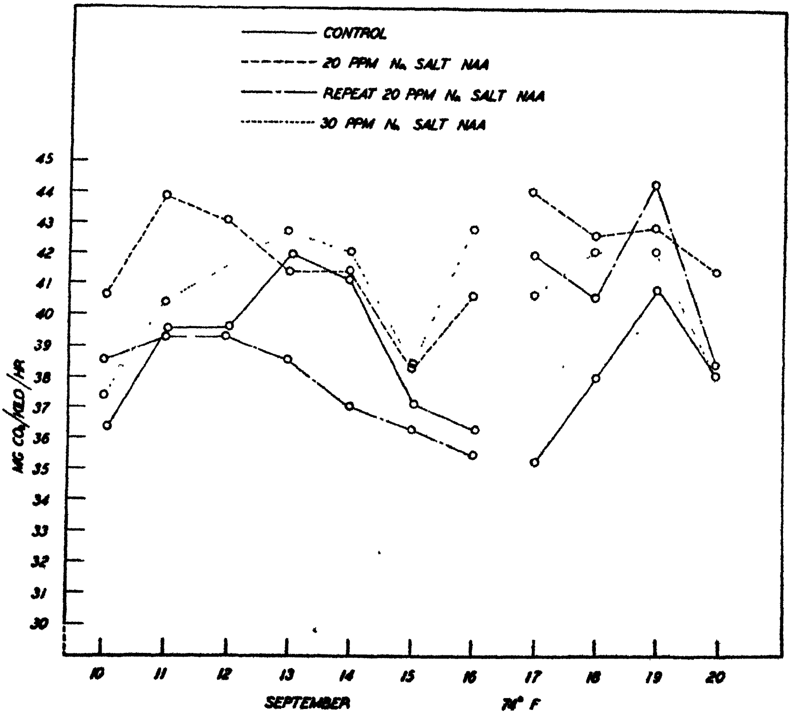

FIG. 8. Effect of limb sprays of sodium salt of a-naphthalene acetic sprays on respiration of Wealthy apples at 74 degrees F. Sprayed September 2, 1946. "Repeat" treatment given second spray on September 6, 1946. Harvested September 9 and 16, 1946.

and then was sprayed again with the same concentration on September 6. Fruits were harvested on September 9 and 16. Normal abscission was starting on September 9 and was serious by the 16th. Dropping was so serious by the time of the second picking that proper sampling was interfered with.

Fig. 8 reveals that the fruit had almost reached the climacteric peak by the time of the first picking. The 10 parts per million spray results are not included on the graph. During the first 2 days at 74 degrees F, this concentration seemed to have no effect on respiration but during the next 5 days the increase averaged 2.5 milligrams CO_2/kilo/hr. over the control. The repeat 20 parts per million spray might be interpreted as having no effect on respiration judging from Fig. 8 (first picking). On the other hand it might be interpreted that these fruits were post-climacteric when harvested. That is, the stimulatory effect had been more influential during the 7 day period after spraying until harvest. Firmness data support this latter view. The 20 and 30 parts per million sprays had an obviously stimulatory effect on the respiration of the first picking. The second picking data indicates that all three sprays had stimulated respiration. It is difficult to tell from the respiration data which spray had the greatest effect, since all four lots (including the control) were in different positions on the climacteric curve at the time of harvest.

Firmness data on this experiment appear in Table I. In this particular experiment, firmness results are more easily interpreted than respiration results. The data in Table I indicate that in general, the higher the concentration of hormone, the greater was the increase in softening rate. The repeat spray of 20 parts per million had about the same effect as the 30 parts per million spray.

TABLE I—FIRMNESS OF WEALTHY APPLES AS AFFECTED BY SPRAYS OF THE SODIUM SALT OF A-NAPHTHALENEACETIC ACID

Treatment	First Picking; At Harvest; 7 Days After Spraying (Lbs)	First Picking; After Being Held 7 Days at 74 Degrees F (Lbs)	Second Picking; At Harvest; 14 Days After Spraying (Lbs)	Second Picking; After Being Held 5 Days at 74 Degrees F (Lbs)
Control	14.8	13.0	14.6	13.4
10 Ppm	14.5	12.2	14.2	—
20 Ppm	13 9	11.5	13.0	11.5
20 Ppm repeated	13.2	11.3	12.2	10.9
30 Ppm	13.2	11.2	12.4	10.8

McIntosh:—Individual limbs of a McIntosh tree were sprayed with 10 and 20 parts per million of the sodium salt of a-naphthaleneacetic acid on September 16, 1946. Normal abscission did not start until September 22. One picking was made from this tree on September 21 and a second picking on September 24.

Respiration results in Fig. 9 show that both concentrations of this spray had a marked effect on the respiration rate at the first picking. The stronger concentration had a slightly greater effect than the weaker one. At the second picking not enough apples remained on the 10 parts per million sprayed limb for a respiration sample, but it was apparent

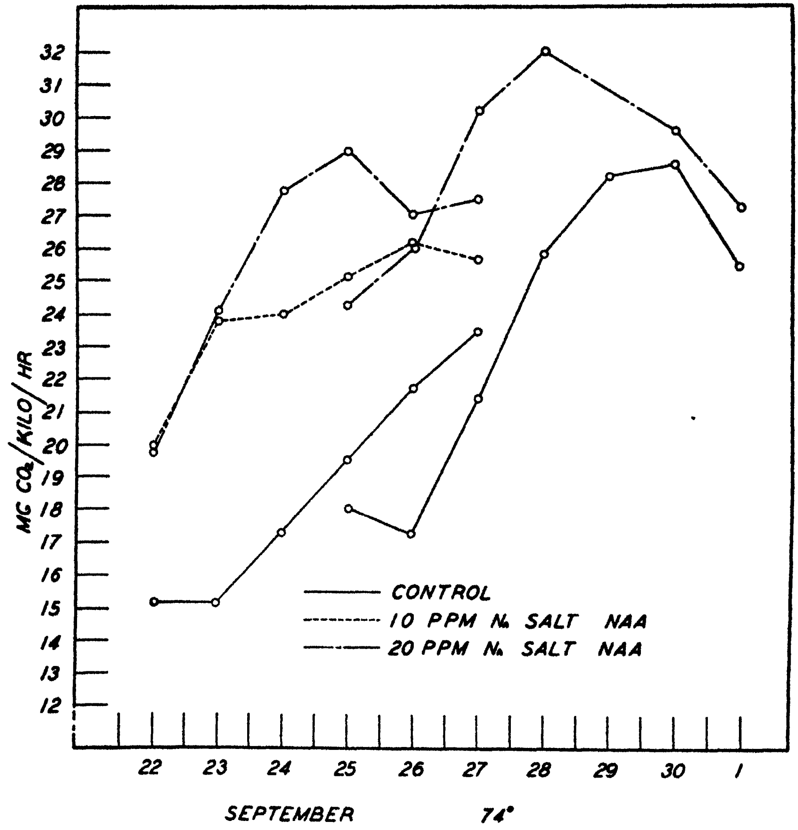

FIG. 9. Effect of limb sprays of sodium salt of a-naphthalene acetic acid on respiration of McIntosh at 74 degrees F. Sprayed September 16, 1946; harvested September 21 and 24, 1946.

that the 20 parts per million spray had a marked effect on respiration rate.

Firmness data showed that fruit from both sprayed limbs was .9 pounds softer than the control fruit at the time of the first picking (that is 5 days after spraying). Fruit from the second picking which had been sprayed with 20 parts per million of the hormone after being held 7 days at 74 degrees F were 1.9 pounds softer than the controls.

A sample of apples from each treatment of the first picking was held at 32 degrees F until December 13, 1946. Pressure test data showed that the fruit sprayed with 10 parts per million had softened .5 pounds more during storage than the control. The fruit sprayed with 20 parts per million softened .7 pounds more during storage than the control. These data took into account the fact that the sprayed fruit was .9 pounds softer than the control (see above) at the time of harvest.

DISCUSSION

The results of this investigation tend to support the findings of Gerhardt and Allmendinger (3) that hormone sprays may *directly* stimulate the respiration and ripening rate of apples. In three out of four years some stimulatory effect of such sprays was noted. The magnitude of such an effect would seem to depend on the following factors: 1, the season; 2, the variety; 3, the concentration of hormone material used; 4, the number of applications made; and 5, the temperature at which the apples are held. The effects of such sprays are much more apparent at high temperatures (74 degrees F) than at low (33 degrees F); 6, the interval between spraying and harvesting. Gerhardt and Allmendinger (3) and Allen and Davey (1) have pointed out that such direct stimulatory effects were not noticed until about 2 weeks after spraying. This study had shown that such an effect may be noted within 3 days after spraying on some varieties in some seasons.

This report and that of others (1, 3) emphasize that if apples are sprayed with abscission delaying sprays, the harvesting season should not be delayed too long after spraying. If high concentration sprays or repeat sprays are used and if the harvesting period is very much extended, the sprayed fruits should not be stored too long.

Before dip treatments of a-naphthaleneacetic acid are recommended for scald control, their effect on ripening should be fully examined. This study showed that such treatments may stimulate ripening at a high temperature (74 degrees F).

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The Fog Machine for Applying Pre-Harvest Drop Materials to Apple Trees[1]

By C. L. HAMNER and E. J. RASMUSSEN, *Michigan State College, East Lansing, Mich.*

EARLIER work (1) indicated that the Todd Insecticidal Fog Applicator (fog machine) might be used for dispersing certain agricultural chemicals, such as growth regulating substances which are effective on plants in very small amounts. Thompson and Batjer (2) showed that naphthalene acetic acid in an oil emulsion, applied at the rate of 5 gallons per acre by airplane gave comparable results to applications in water applied at the rate of 500 gallons per acre made with a regular high pressure sprayer. Tukey and Hamner (3) found that a concentrated solution of naphthalene acetic acid could be applied in aerosol form to delay the dropping of apples and it was thought that this material might be applied effectively and rapidly with a fog machine which has the capacity to produce a large volume of aerosol.

MATERIALS AND METHODS

A Todd Insecticidal Fog Applicator was used to apply the growth regulating material.[2] This machine creates a hot air stream (250 to 1300 degrees F) which is forced through a flexible metal hose to a nozzle. The growth regulating substance in concentrated form in oil was injected into the hot air stream at the nozzle where it vaporized immediately, forming a dense fog.

The growth-regulating substance used was naphthalene acetic acid in oil. Twenty grams of naphthalene acetic was first added to 50 cubic centimeters of Tween emulsifier; next, 100 cubic centimeters of water was added and this mixture added to 1 gallon of Horticultural oil made by the Shell Oil Company.[3] A vigorous shaking of the solution gave a satisfactory emulsion for use in the fog machine.

When the fog machine was in operation it was set to deliver 40 gallons of oil per hour. This produced a fog that we designated as a wet fog in that it was wet enough to stick to the foliage. Dry fog could be produced but it was questionable whether very much of a deposit could be obtained on the trees by a dry fog.

Trees which are ordinarily sensitive to the pre-harvest sprays were used as experimental material. An early maturing apple, Oldenburg, was used for the test.

On August 8, 1946, five Oldenburg trees were "fogged" with naphthalene acetic acid in oil, and on August 15, 1946 a repeat application was made. The apples were just beginning to drop on the trees when the first application was made. The temperature of the air at the time of treatment was between 80 and 85 degrees F. The season was "very

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[1] Journal article No. 853 (n.s.) of the Michigan Agricultural Experiment Station.

[2] Todd Shipyards Corporation, 601 West 26th St., New York, New York.

[3] This is a special oil prepared by the Shell Company. It is non-toxic to plants.

dry," with less than 2 inches of rain in July and August. No rain fell during the course of the experiment.

A noticeable deposit of oil was readily visible after the first application on the lower leaves and fruit, but not on the upper part of the tree. The amount of oil applied per tree was about 1 pint. Only a small fraction of this, however, was deposited on the tree. The fog drifted through the other nearby trees and was estimated to have carried for about ¼ mile before it was dissipated.

In order to compare the fog machine with the standard practice, two trees were sprayed on August 8, 1946 with Parmone using a high pressure water sprayer.

RESULTS

The naphthalene acetic acid in the "fogging" treatment was slightly more effective in delaying the pre-harvest drop of Oldenburg up to 12 days after application (Table I), than was the standard method of water-spray application. On August 17, 4.9 per cent of the apples had dropped on the "fogged trees", 7.0 per cent on the water-sprayed trees, and 21.1 per cent had dropped on the untreated checks.

TABLE I—EFFECT OF NAPHTHALENE ACETIC ACID IN OIL APPLIED WITH A "FOG MACHINE," AND IN WATER WITH A HIGH PRESSURE SPRAY PUMP ON THE AMOUNT OF PRE-HARVEST DROP OF OLDENBURG APPLES*

Material	Concentration	Method of Application	Per Cent of Drop					
			Aug 13	Aug 15	Aug 17	Aug 20	Aug 21	Sep 9
Naphthalene acetic acid in oil	20 grams per gallon	Fog machine	0.5	1.1	4.9	10.5	16.1	36.0
Naphthalene acetic acid on water	10,000 ppm	High pressure sprayer	0.5	2.4	7.0	12.7	14.1	37.5
Check.............			1.7	5.8	21.1	40.1	53.5	100.0

*The trees were bearing a heavy crop of fruit. The number of fruits per tree varied from 56,000 to 62,000.

Observations on the "fogged" trees 7 days after the first application showed some injury to the foliage and some oil deposit on the fruit on the part of the trees nearest to where the fog machine had passed. The fruit on the "fogged" trees was more highly colored and ripened faster than on the unsprayed trees.

SUMMARY

The fog machine has been used successfully for the application of naphthalene acetic acid as a pre-harvest spray to prevent drop of Oldenburg apples.

The ease and rapidity of application by the fog machine are attractive features. The uncontrolled drift of the fog and its response to the slightest air currents are limiting factors in its use by fruit growers at the present time.

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The Effect of Environmental Conditions Prior to Ripening on Maturity and Quality of Date Fruit

By Roy W. Nixon and Walter Reuther, *U. S. Department of Agriculture, Indio, Calif.*

Fruit of the date palm is borne on a few relatively large clusters or bunches. Commercial date growers in the United States cover the bunches to protect them from rains, birds, and insects. Obviously these coverings affect exposure to air currents, light intensity, and temperature and may be expected to have some influence on the ripening and quality of the fruit. This paper presents attempts that have been made to evaluate some effects of these environmental factors on date fruits.

1942 Experiments — Bunch Coverings

In thinning experiments with the Halawy date (2) it was observed that a larger proportion of fruit shriveled in the outer portion of the bunch than in the center. In 1942 further studies were made to determine whether the greater exposure of outside fruit to light and air currents might explain the higher incidence of shrivel in that part of the bunch. At the Martinez Research Station in Coachella Valley, California, all inflorescences on 32 Halawy palms, 7 to 9 years of age, were pollinated with pollen from the same male palm. At the end of the pollination season, or about 6 weeks after the first pollinations, the fruit was thinned by removing about 62 per cent of the total amount of each bunch. On half of the palms 25 per cent of the fruit was removed by cutting out strands and 50 per cent of the remaining fruit by cutting back strands; on the other half of the palms 55 per cent of the fruit was removed by cutting out strands and 15 per cent of the remaining fruit by cutting back strands. All palms carried eight to ten leaves per bunch and the irrigation treatment was also the same.

On August 10, when the fruit had nearly attained full khalal (pre-ripe) color, all bunches were wrapped in light muslin. Two days later half of the bunches on each palm were enclosed in paper cylinders that protected only the sides of the bunches. These paper tubes were made by cutting in half, across the middle, the type ordinarily used for covering Deglet Noor bunches. The upper edge of the tube was attached by clothespins to the strands just above the fruiting area, or to the upper part of the muslin wrap. The tubes were attached with the upper end open to avoid the accumulation of heated air that occurs when tubes closed at the top in the usual manner are exposed to sunlight, and also to permit comparable exposure of all bunches in event of rain.

On September 14 to 18 fruit counts were made on typical strands to determine the percentages of shriveled and of ripe fruit. Fruit showing wrinkling of the skin while still retaining khalal color was counted as shriveled and fruit that had lost the khalal color and was softening was counted as ripe. The fruit was picked on September 25 and again on October 14 and each time graded according to current commercial standards in Coachella Valley, California. These two pickings were estimated to have removed more than 80 per cent of the fruit and no record was made of what was left. The data are summarized in Table I.

TABLE I—EFFECT OF BUNCH PROTECTION AND FRUIT THINNING ON RIPENING, SHRIVEL, AND GRADE OF HALAWY DATES (1942)

	Most of Thinning Done by Removing:			
	Tips of Strands		Center Strands	
	With Tubes	Without Tubes	With Tubes	Without Tubes
Fruit ripe before first picking (per cent)	17.4	25.4	19.4	25.8
Fruit shriveled before first picking (per cent)	24.2	25.0	16.0	18.0
Fancy, or No. 1, grade (per cent)	20.9	12.3	26.5	15.4
Choice, or No. 2, grade (per cent)	50.0	47.9	49.7	51.3
Dry grade (per cent)	23.6	35.8	18.6	28.5

RESULTS

The following effects of treatment (Table I) were statistically significant (as tested by Students' "t" Method): a slight retardation in ripening due to the paper covers; a little increase in khalal shrivel as a result of fruit thinning by cutting back strands as compared with cutting out strands; an increase in No. 1 fruit and a decrease in dry fruit as a result of the protection afforded by the paper tubes. Somewhat less significant, still above the 5 per cent level, was an increase in dry fruit due to cutting back strands. It will be noted that fruit counts before picking showed no difference in shrivel on the unprotected versus protected bunches comparable to the difference in the dry grade of fruit. This may be explained by weather conditions during the season. August and early September were relatively cool for this time of the year and without abnormally low humidity. From about the middle of September to early October, when the bulk of the fruit was ripening, relatively high temperature and low humidity prevailed. This undoubtedly accentuated drying after the fruit counts were made. Dry weight per fruit, as determined from samples of ripe dates, was not measureably affected by the treatments.

1943 EXPERIMENTS — BUNCH COVERINGS

Experiments with fruit coverings were continued in 1943 with 8-year-old palms of the Khadrawy variety at the United States Date Garden. Fifteen pairs of palms were used. On one palm of each pair all bunches were thinned by cutting out entire strands from the center so as to remove 50 per cent of the total number of fruits and then by cutting back the tips of the strands enough to remove 10 per cent of the fruits remaining (treatment C). On the second palm of each pair 25 per cent of the total number of fruits on each bunch were removed by cutting out entire strands from the center and then 40 per cent of those remaining by cutting back the tips of the strands (treatment T). The total reduction in each thinning treatment was approximately the same, 55 per cent. Thinning was done at the end of the pollination season. At the same time all bunches in excess of 4 per palm were removed so that there were nine or more green leaves for each bunch retained.

On July 27–28 all bunches were wrapped with cotton gauze. In addition, paper coverings were put on so as to have four sub-treatments on each palm as follows: 1, check — gauze only; 2, regular brown paper tube used with the Deglet Noor variety and attached, as is customary, to the fruit stalk above the strands with the open end reaching below the tips of the strands; 3, a shorter section of the same type of paper tube, attached in the same way, but with the open end not extending below the uppermost, or proximal, fruits; 4, the same as 3 with the addition of a separate strip or section of the same paper tubing attached to the sides of the bunch, the upper end being opposite the uppermost, or proximal, fruits and the lower end extending a little below the lowest, or distal, fruits. This strip was held to the sides of the bunch by clothespins attached either to strands or to the gauze, and was similar to the strips used to protect Halawy bunches in 1942. The upper section of paper tubing was added to provide protection in event of rain and was flared outward, umbrella-fashion, so as to provide a protected opening between it and the upper end of the lower section. The purpose of an opening both below and above the fruiting area of the bunch was to promote better ventilation of the fruit.

The fruit was just beginning to take on khalal color at the time the bunches were covered. On August 30 all bunches were examined for maturity and shrivel and fruit counts were made on three typical strands on each bunch. At the same time, notes were made on the presence and severity of sunburn on fruitstalks and strands. The crop was harvested in two pickings, September 8 and 30, and grade records were obtained from each picking. Samples for dry-weight determinations were taken from the first picking.

RESULTS

No significant differences in shrivel showed up in these experiments. In partial explanation it should be noted that the Khadrawy variety is not as susceptible to shrivel as is Halawy. This was not a year in which much shrivel occurred in Khadrawy fruit as it ripened throughout Coachella Valley. Furthermore, the experimental palms were small, only 6 to 8 feet to the buds, with the tips of the lower leaves of most of them touching the ground. The small size of the palms and their location in a block surrounded by much higher palms tended to minimize exposure of the fruit to air currents.

There were no significant differences in weight of fruit, either fresh or dry, or in the percentages of fruit in the different grades.

Some degree of sunburn, mostly slight to moderate, on either fruitstalks or strands or both, resulted from the use of the brown paper covers. Out of 30 bunches in each treatment the number affected with sunburn was as follows: commercial paper covers, 22; short umbrella sections above fruit zone, 14; umbrella above with short section around fruit beneath, 18; check with gauze alone, 3.

Again, the use of covers was found to have slightly delayed ripening, as shown by the data from fruit counts in Table II. Differences were significant at the 1 per cent level between treatments 3–C and 2–C and at the 5 per cent level between 3–C and 4–C, and between 1–T and 4–T.

TABLE II—PERCENTAGE OF KHADRAWY FRUIT RIPE ON SEPTEMBER 1, 1943

	Thinning Done by Removing	
	Center Strands (C)	Tips of Strands (T)
1. Check, gauze alone	28.6	33.8
2. Brown paper tube, full length	20.4	25.6
3. Brown paper "umbrella" above	37.4	32.4
4. "Umbrella above", separate short section around fruit beneath	24.0	22.8
Difference required for significance:		
5 per cent level	12.1	10.7
1 per cent level	17.0	15.1

1944 EXPERIMENTS

The same Khadrawy palms were again used in 1944 for experiments planned with the twofold objective of studying exposure as it affects 1, the fruit stalk and conductive tissue; and 2, the fruit itself. All bunches were treated uniformly as regards pollination and thinning. The tips of the strands were cut back at time of pollination enough to remove 10 to 15 per cent of the flowers, and on May 22 and 23 the center strands were cut out to remove about 50 per cent of the fruit remaining. The dry weight of fruit was determined from composite samples at intervals during the khalal stage up to and including the first picking. A few studies of temperature in fruit bunches were made during the latter part of August and early September. Just before the first picking, each bunch was examined for maturity and shrivel. In doing this, fruit on the side of the bunch most exposed to the sun was compared with that on the least exposed side and in the center. The dates on two strands being counted for each record. The fruit was harvested in two pickings, the first September 29 to 31 and the second on November 3. Grade records were obtained from each picking.

All the palms this year were in plots used for irrigation experiments in which ample irrigation, as indicated by maximum leaf elongation, was compared with inadequate irrigation in late summer, as indicated by leaf elongation at about three-fourths the growth rate of the others. Records for the palms were assembled in two groups accordingly.

Exposure of Fruitstalks:—On each of 13 of the palms 6 different treatments were applied on July 6 and 7 to fruitstalks: 1, check, no covering; 2, insulated with layer of corrugated asbestos paper, placed between muslin, wrapped around fruitstalk; 3, black cloth wrapped around fruitstalk; 4, white cloth wrapped around fruitstalk; 5, black cold-water paint applied to fruitstalk; and 6, white cold-water paint applied to fruitstalk. By the end of July some brownish discoloration was beginning to show under the black cloth and the black paint, indicating injury to the tissue. On August 23 an inspection showed no injury on fruitstalks in treatments 1, 2, 4, and 6. In the other two treatments injury was found as follows: No. 3, 7 severe, 2 moderate, 3 slight; No. 5, 7 severe, 1 moderate, 3 slight. On September 15, less than 2 per cent of the fruit was severely shriveled in treatments 1, 2, 4, and 6; but in treatment 3 there was 37 per cent and in treatment 5, 17 per cent. There was a reduction in top grade (choice or better) more or less paralleling these differences. The high percentage of severe shrivel for fruitstalks covered with black cloth and black paint was obviously the result of severe sunburn which caused premature and severe shrivel of all the fruit on four bunches in treatment 3, and on two bunches in treatment 5. This was reflected in the grade records. The severely shriveled dates were either substandard or culls and these two classifications together accounted for 33.7 per cent of the fruit in treatment 3 and for 25.8 per cent of the fruit in treatment 5, the percentage in the other treatments being for 1, 3.3 per cent; for 2, 4.7 per cent; for 4, 4.7 per cent; and for 6, 10.3 per cent.

Excluding the bunches on which all fruit was severely shriveled, there were no significant differences in ripening between treatments. There were differences in ripening correlated with exposure and with irrigation treatment, but these parallel so closely those presented in the next section that the latter may be taken as representative.

Exposure of Fruit:—Fourteen palms were used in experiments to study the effects of varying exposures on the fruit. On August 9 and 10, four different treatments were applied, each to one bunch on every palm, as follows: 1, check, no covering except cheese cloth, necessary to protect fruit from birds and insects and included in all treatments irrespective of other covering; 2, regular brown paper tube in general use at present; 3, the same type of bag as that used in 2, but covered outside with aluminum paint; and 4, a white bag similar to that used in 2 except for the white color and lighter weight. At the time the bunches were covered the fruit was just entering the khalal stage, most of it being from one-fourth to one-half colored.

By the end of August some burning of fruitstalks and strands was observed under the aluminum-painted bags. On September 11 and 12, when fruit maturity data were obtained, a count of the total number of strands sunburned in each treatment showed that there were 18 on the check bunches, 198 under the brown covers, 243 under the aluminum-painted covers, and 18 under the white paper covers. Four bunches under the aluminum-painted covers were so badly sunburned that all the fruit was severely shriveled. These four bunches were excluded in obtaining the data on ripening and slight shrivel, shown in Fig. 1. Fruit on the check bunches ripened ahead of that under covers, but as between the different types of covers there was no difference in this respect. Fruit on the most exposed strands, whether under covers or not, was consistently more advanced in maturity than that on the center strands; and in every case fruit in the dry plots ripened ahead of that in the wet plots. Fruit on the least exposed strands was intermediate in ripening between that most exposed and that in the center of the bunch; the data are omitted from Fig. 1.

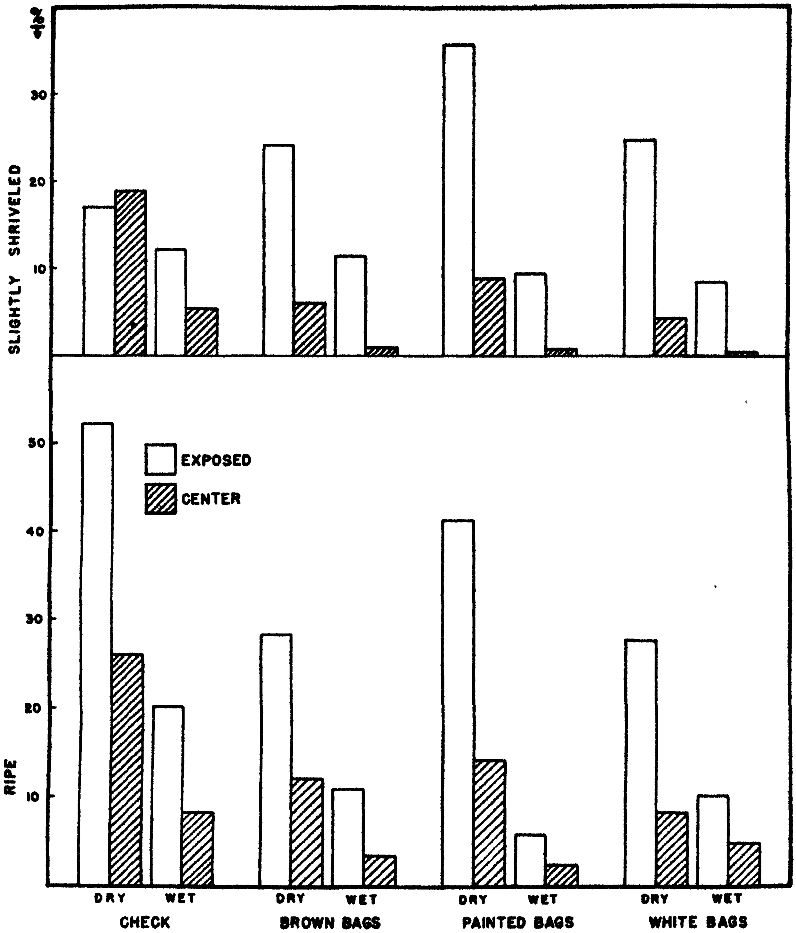

FIG. 1. Slight shriveling and ripening of Khadrawy dates as affected by bunch coverings, position of fruit on the bunch, and soil moisture.

A definite change of color from the khalal yellow to amber brown accompanied by softening of flesh was taken as the criterion of ripening. At the same time, a count was also made of fruit listed as slightly shriveled as indicated by slight wrinkling of the skin without loss of khalal color or pronounced softening. The degree of shrivel was not differentiated in previous records. The percentage of this slightly shriveled fruit paralleled that listed as ripe with the exception of the dry plot check. This suggested that a slight shrivel of this type might be an accompaniment of advanced maturity and not necessarily an indication of any abnormality in the ripening process.

Respiration of Fruit:—In Table III are presented some respiration and dry weight data obtained the previous year which tend to support

TABLE III—THE RESPIRATORY ACTIVITY OF KHADRAWY DATES IN RELATION TO MATURITY (1943)

Sample* No.	Date Picked	No. Fruits in Sample	Vol Per Fruit (Ml)	Dry Weight Per Fruit, Without Seed (Gm)	Water Per Fruit (Gm)	Respiratory Activity Mg CO_2 per Hour		Maturity and Condition of Fruit
						Per Kg Fresh Wt (With Seed) (Mg)	Per 100 Fruits (Mg)	
A 1	Aug 10	70	14.8	4.67	8.7	27.6	41.1	Khalal—plump
A 2	Aug 10	58	13.9	5.62	7.2	46.4	65.9	Khalal—shriveled tips
A 3	Aug 10	86	11.0	6.31	6.3	6.5	8.8	Late rutab (ripe)
B 1	Aug 12	70	15.6	4.65	9.5	28.4	44.5	Khalal—plump
B 2	Aug 12	70	14.3	6.11	7.4	40.0	59.5	Khalal—shriveled tips
B 3	Aug 12	80	12.3	6.39	6 0	12.0	15.8	Late rutab (ripe)
A 4	Aug 30	57	16.9	5.75	8.3	30.5	46.9	Khalal—plump
A 5	Aug 30	66	15.1	6.10	6.7	44.8	62.7	Khalal—shriveled tips
B 4	Aug 30	66	15.8	5.55	9.1	23.6	37.9	Khalal—plump
B 5	Aug 30	66	14.3	6.42	7.2	46.3	68 6	Khalal—shriveled tips

*Samples in the "A" series were obtained from four tagged bunches (two on each of two palms) that were all pollinated on the same date, February 22, 1943. Samples in the "B" series were obtained in a similar manner from another comparable group of palms and marked bunches.

the above hypothesis. Note that khalal fruit with shriveled tips without exception had accumulated more dry matter than corresponding plump fruit picked from the same bunches at the same time, and less dry matter than fully ripe fruit. Respiration measurements made on these same lots of fruit indicated that these khalal fruits with shriveled tips had a much higher respiration rate than either plump khalal or ripe fruits. This suggests that a slight shriveling in the khalal stage may be associated with a climacteric rise in respiratory activity just before the fruit begins to soften and break down. However, further study will be required to establish definitely that khalal Khadrawy dates having a slight amount of shrivel exhibit a climacteric rise in respiration before ripening that is analogous to the behavior of deciduous fruits. Some Khadrawy dates begin to soften and break down without any preliminary shriveling in the khalal stage. The Deglet Noor variety appears to soften and break down without going through any preliminary rise in respiratory rate (3), but more detailed studies are needed before definite conclusions can be reached.

Dry Weight of Fruit:—During the 1944 season, additional dry weight data were obtained which confirmed these results. Dry weight determinations were made of eight paired samples of fruit, each from the same bunch, normal plump khalal fruit being compared with fruit of the same size and color, but with the skin slightly wrinkled. Care was taken to obtain samples only from entirely normal strands and fruitstalks showing no traces of sunburn. The average dry weight per fruit for the plump dates was 5.09 ± 0.26 grams (standard error) and for the slightly shriveled or wrinkled dates, 6.21 ± 0.25 grams. The difference tested according to "Student's method" is highly significant. Later some of these slightly shriveled khalal fruits on the palm were marked with India ink, and after becoming fully ripe they differed little in appearance from fruit that lost khalal color without wrinkling before softening.

On the other hand, fruit severely shriveled has been previously found lower in dry weight than normal fruit on the same bunch in the case of Halawy (2). On Khadrawy it was not possible in these experiments to obtain a series of samples of severely shriveled fruits from strands and fruitstalks entirely normal and uninjured because almost none could be found. When selected without regard to strand injury, ten paired samples of ripe fruits, each from the same bunch, gave dry weights as follows: normal, 7.01 ± 0.15 grams; and severely shriveled, 4.85 ± 0.15 grams. The difference is highly significant.

In several tests, strand injury from severe sunburn was simulated by immersing a portion of the strand (2 to 3 inches) between the fruit and the fruitstalk in boiling water for 1 to 3 minutes. Although the treated area became dark brown and shrunken within a day or two following, the fruits, all in the early khalal stage, remained plump for several days before wrinkling of the skin gave evidence of shrivel. Within 2 to 3 weeks fruits on the treated strands became severely shriveled, evidently as a result of a cessation of the influx of dry matter.

Dry weight determinations from composite samples in the different bunch treatments did not show differences that could be correlated with the type of covering used, although the last sampling of ripe fruit showed a lower weight from fruit under the aluminum-painted covers, which appeared to be due to the large percentage of severely shriveled fruit.

Grade Records:—About one-third of the fruit from under the aluminum bags was graded as substandard because of severe shrivel. Fruit from the check bunches was somewhat drier than that from the covered bunches. Otherwise grade records for the different treatments were more or less comparable.

Temperature Studies:—In a few temperature studies during late summer, thermocouples were inserted about 1 millimeter into the flesh of dates in different locations on the bunch — the most exposed side, the least exposed side, and in the center — and temperatures were recorded from potentiometer readings at intervals around the clock. A typical record for a Deglet Noor bunch is shown in Fig. 2. During the first half of the 48-hour period, the bunch was covered only with cotton gauze; during the second half, a brown paper tube or bag of the commercial type was placed over the gauze-covered bunch.

Fruit temperatures on the most exposed side of the bunch were higher than in other parts of the bunch for 6 or 7 hours during the day, the difference becoming as much as 10 degrees C shortly after noon. Bagging prolonged the period during which the temperature of the outer fruit was higher, and the inner fruit lower, than air temperature. Before bagging, the temperature of fruit in the center of the bunch was below outside air temperatures from about 9 a. m. to 2 p. m. and was warmer than outside air temperatures from about 5 to 9 p. m. After bagging, these differences were somewhat accentuated and prolonged.

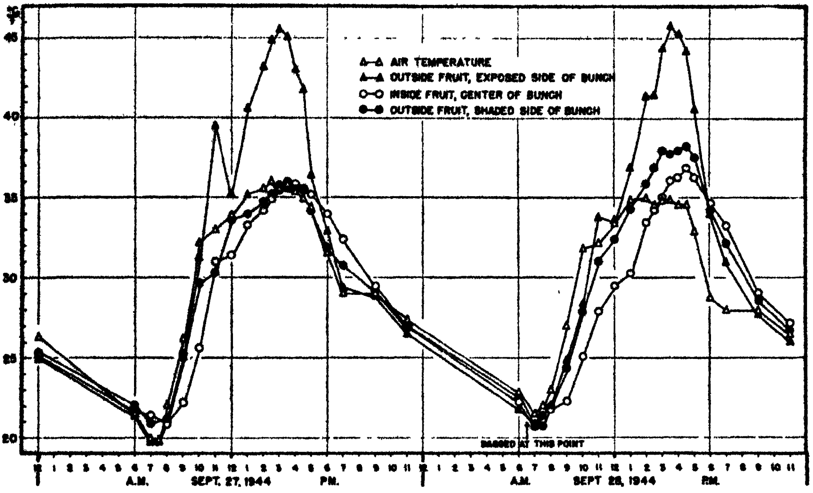

FIG. 2. Effect of exposure on temperature of date fruit.

A number of temperature readings were obtained from mercury thermometers in different parts of Khadrawy bunches. Early in the afternoon of a typical summer day in August, when the air temperature outside was 40.6 degrees C, a temperature of 67.3 degrees C was recorded on the inside of, and touching, that part of a brown bag exposed to direct sunlight. Comparable readings from beneath white bags under similar conditions were 8 degrees to 17 degrees C lower. Studies that have been reported with other plant tissues suggest that definite injury could be expected from a temperature as high as 66 degrees C. However, only fruit or strands touching or very close to the exposed part of the bag would be likely to be affected since, at the same time that 67.3 degrees C was recorded as above indicated, the center of the open space above the fruit under the bag was only 46 degrees C. This explains the fact that discoloration from sunburn was observed mostly on the most exposed portions of the bunch under the brown bags. Except adjacent to the exposed portion, temperatures under the white bags were comparable to or only slightly lower than those under the brown bags. Temperatures under gauze covers were comparable to those under white paper. Temperatures in the center of the bunch in the fruit zone were 3 degrees to 6 degrees C lower than outside air temperature during the middle of the day.

1945 EXPERIMENTS

Sunburn of Fruitstalks:—Untreated fruitstalks were compared to those covered with white coldwater paint in 50 pairs of bunches on Khadrawy palms. There were no significant differences in the grades of fruit resulting from these treatments exclusive of six of the untreated fruitstalks. On these six bunches substandard fruit (mostly severe shrivel) accounted for 24 to 98 per cent of the total amount per bunch, whereas on the bunches whose fruitstalks were covered with white cold-water paint there was none with more than 20 per cent. This difference is believed to have been due to sunburn of the untreated fruitstalks, but, although slight injury had previously been noted, no detailed observations were attempted until October 4 and this was too late to check differences, as too many strands, and in some cases the fruitstalks itself, had begun to die back because of all the fruit being fully ripe.

Humidity in Relation to Fruit Rot:—The 1945 season was characterized by heavy loss from fruit rot as the result of high humidity and rain between late July and early September. Fourteen of the same kind of white paper tubes or bags as those tried in 1944 were used on as many palms along with the fruitstalk treatments mentioned in the preceding paragraph. Total yields were not recorded, but from notes made on all bunches and fruit samples therefrom losses from rot were estimated at about 70 per cent for fruit under the bags as compared with 15 per cent for fruit not bagged.

The development of fruit rot in the centers of bunches under bags was observed from time to time prior to harvest. During the later part of August a few determinations of humidity in the centers of bunches were made from wet-bulb and dry-bulb readings with an aspirator type of psychrometer. On clear but rather humid days the relative humidity in the center of bunches under paper covers was 10 to 15 points higher than in bunches covered only with gauze and in the latter it was 10 to 15 points higher than the air outside. Several different times when examined during the forenoon, dates in the center of a bunch under paper covers were found to be covered with moisture. This was not observed in bunches covered only with light cloth. The lower temperature of fruit in the center of the bunch in combination with the higher humidity under the paper cover, would explain the condensation of moisture. Evidently, the surface temperature of fruit in the center of the bunch at times reaches the dewpoint for the atmosphere inside the bunch.

DISCUSSION AND SUMMARY

During the years 1942 to 1945 inclusive studies were made of Halawy and Khadrawy dates as they ripen on the palm in Coachella Valley, California. The resulting data indicate that several different factors involved in exposure affect maturity and fruit quality.

1. Fruit on that part of a bunch of dates most exposed to direct sunlight ripened a little ahead of the rest of the bunch. This occurred even when the bunch was covered with paper. It is apparently explained by records showing that these more exposed fruits are subjected to higher temperatures for several hours during the day.

2. Paper covers placed over the bunches caused a slight retardation in ripening of fruit. Differences in temperature probably were not sufficient to account for this. It seems more likely that a reduction in rate of dehydration of the ripening fruit is involved. Several investigators (1, 4, 5) have shown that ripening of dates is accompanied by a decrease in moisture content which starts in the early stages before the fruit becomes edible. Reuther and Crawford (3) found that cover-

ing Deglet Noor fruit with wax emulsion at about the beginning of the khalal stage reduced shrivel and delayed ripening. Protecting the entire bunch with paper covers of the type at present used on Deglet Noor probably affects the fruit in a somewhat similar manner by reducing exposure to the drying effects of air currents, thus increasing the relative humidity within the bunch. The higher humidity under the paper covers was evidenced by condensation of moisture on the surface of the fruit in the center of the bunch, which was observed a number of times during the forenoon, and also by the very high incidence of fruit rot under the covers during the very unfavorable season of 1945.

3. Brown paper covers over the bunch increased the sunburn, as was indicated by discoloration of strands beneath. This did not occur under white paper covers. Only in case of very pronounced and obvious injury from sunburn was there any apparent effect on fruit quality, resulting in a high percentage of severe shrivel.

4. Evidence was obtained of two kinds of shrivel in the Khadrawy date: (a) slight shrivel, first recognizable from a slight wrinkling of the skin of the fruit while still retaining its khalal color, was associated with exposure to air movement and high temperature and with reduced soil moisture in late summer. Apparently this mild type of shrivel does not necessarily affect quality unless the drying conditions are long continued, in which event there may be an increase in the drier grades of fruit. In the Khadrawy variety very slight wrinkling of the skin just preceding definite softening was associated with greater respiratory activity of the fruit and with greater dry weight, in comparison with non-wrinkled fruit of the same size and color. (b) Severe shrivel, resulting in a pronounced reduction in dry matter of the ripe fruit and a large proportion of substandard and cull fruit, was associated with definite injury to the strands or fruitstalk.

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Modified Atmospheres in Relation to the Transportion of Deciduous Fruits

By L. L. CLAYPOOL, and F. W. ALLEN, *University of California, Davis, Cal.*

ALTHOUGH presented by Berard (3) and recognized by the French Academy of Sciences one and a quarter centurys ago, the idea of the possible benefits of modified atmospheres for fruit preservation attracted relatively little attention until Kidd and West (8) began their extensive "gas storage" studies on apples, and Brooks (4) and his associates began their shipping tests in the control of Monilia on peaches and Botrytis of strawberries. The results of these investigators have clearly shown the value of modified atmospheres in retarding tissue softening and the development of mold growth. Since their first publications, numerous investigators interested in storage and shipping problems have worked upon the possibilities and limitations of modified atmospheres.

Transit studies have been directed toward the use of carbon dioxide as a supplement to refrigeration (1, 2, 5). It seemed desirable also to investigate the effect of modified atmospheres for transit periods (10 days) at temperatures well above those found in cars under refrigeration. This report for the season of 1946 on the holding of Santa Rosa plums, Bartlett pears, Primose peaches and Thompson Seedless and Tokay grapes, for transit periods only, presents the results secured in fruits held in a range of O_2 as well as CO_2 levels at 65 degrees F, and compares these results with air or modified atmosphere lots held at refrigerator car temperatures.

PROCEDURE

Except for the Santa Rosa plums which were from an orchard in the Sierra Nevada foothills in Placer County, the fruits used in these experiments were all grown in the experimental orchards and vineyards at Davis. After harvest all fruits were carefully sorted and graded into lots of uniform size and maturity. Each lot weighing about 1200 to 1300 grams depending on the kind of fruit, was placed in a 3500 cubic centimeter wide mouth jar to which was attached through the metal cover an inlet tube extending to the bottom of the jar and an outlet tube at the top.

After the jars were sealed, as indicated by testing at several pounds air pressure, continuous flows of gas of the desired mixtures were passed through them. The flows were regulated by flowmeters similar to those described for use in respiration studies by Claypool and Keefer (6). Where two or more gases were required to obtain the desired CO_2 and O_2 concentrations, separate flowmeter boards were used for each gas in the mixture. By combining the proper flow of gas from a flowmeter on each board it was possible to secure any desired mixture and rate of flow. For example, if a gas mixture containing 10 per cent CO_2, 2.5 per cent O_2 and 87.5 per cent N_2 was desired at a rate of flow of 100 cubic centimeters a minute, it could be readily secured by combining the flows of 10 cubic centimeters—CO_2, 12 cubic centimeters—air and 78 cubic centimeters—N_2. Most of the tests were made using a rate of flow of about 100 cubic centimeters per minute at 65 degrees F, and about 50 cubic centimeters per minute at 40 degrees F, which resulted in an atmospheric change every 20 minutes and 40 minutes respectively.

After 10 days under constant conditions of temperature and atmosphere all lots were removed from the jars and placed in air at 65 degrees F until observations on them were completed. Color change, rate of softening and flavor were the important factors observed except for grapes, where stem condition and decay are perhaps the most important considerations. Color was expressed numerically by assigning arbitrary numbers to designate color so that the riper the fruit the higher the numerical value.

The color values used for Santa Rosa plums are shown in Table I.

TABLE I—NUMERICAL EXPRESSION OF SANTA ROSA PLUM COLOR

Numerical Rating	Fruit Color	Commercial Rating
1	Less than 25 per cent light red	Immature
2	Less than 50 per cent light red	40 per cent minimum legal maturity
3	Less than 75 per cent light red	Wholesaler preference
4	Less than 100 per cent light red	
5	Light red	Acceptable to retailer
6	Medium red	
7	Medium dark red	Acceptable to consumer
8	Dark red	
9	Turning black	Unsaleable
10	Black	

The color values for Bartlett pears do not cover the wide range found in some plum varieties since the development of red pigment is not a factor. The color values used for Bartlett pears are shown in Table II.

TABLE II—NUMERICAL EXPRESSION OF BARTLETT PEAR COLOR

California Color Chart		Numerical Color Rating Used	Commercial Rating
Numerical Rating	Color Rating		
1	Green	1	Doubtful maturity
		2	
2	Light green	3	Acceptable to wholesaler
		4	
3	Yellowish green	5	Acceptable to retailer
		6	Acceptable to consumer
4	Yellow (full ripe)	7	
		8	

The Utah (7) color chart, used as a guide in determining the numerical color value of peaches, separates the fruit into five color stages from minimum harvest maturity to full ripeness. For the purposes of our records, the fruits were divided into narrower color ranges by placing those fruits intermediate between two colors into another group and renumbering all of the groups accordingly.

The average color of any lot of fruit was determined (a) by multiplying the number of fruits in each color range by the numeral assigned to that color, (b) adding the products of multiplications, and (c) dividing this sum by the number of fruits in the lot.

No attempt was made to rate the color of grapes as changes after harvest are negligible. Softening was rated by touch rather than by pressure test.

Santa Rosa Plums:—At the time of harvest, the plums used in these experiments were given a numerical color value of 4. Most fruits were only slightly less than full light red color. This stage of development is the one most desired by Eastern receivers after the fruit arrives on the wholesale market.

As shown in Table III, all of the different lots were removed in excellent condition after being held for 10 days at a temperature of 40 degrees F. Little color change had occurred in any lot and all lots were similar. At this temperature, ripening apparently was retarded no more in the modified atmospheres than in air. After removal of the different samples to 65 degrees F air for ripening, color development in the air or check lot of fruit was observed to be somewhat more rapid than in the low oxygen or high carbon-dioxide lots.

Comparable lots of fruit held at 65 degrees F showed marked differences as illustrated by the data in Table III. When removed from the different atmospheres at the end of 10 days lot 13, held in an atmosphere containing 2.5 per cent O_2, still had a color value of only 4.8 as compared with a value of 4 when harvested. The low oxygen materially retarded color development, both during the 10 day transit period and subsequently. The treatment of lot 14, in which the "air" contained 5.0 per cent O_2 was not so effective.

Lots 15 and 16 held in 10 and 15 per cent O_2 respectively were of equal color intensity with the normal air sample (lot 17). In the CO_2 series, (lots 18 to 24) a concentration of only 2.5 per cent CO_2 proved ineffective. Concentrations of 5 to 15 per cent had some retarding effect while 25 to 60 per cent were most effective. As with the 2.5 per cent O_2 lot, these high CO_2 concentrations reduced color changes to a minimum. The fruit was similar in appearance and remained marketable either as long or longer than the comparable lots held at 40 degrees F. No decay developed in any lot held in 10 per cent CO_2 or above. In the 40 and 60 per cent concentrations, however, the fruits failed to ripen with their characteristic red flesh color, and the flavor was more tart than in the air sample. Lot 22, held in 25 per cent CO_2 and 16 per cent O_2, while definitely retarded in ripening, was normal in both color and flavor development.

Bartlett Pears:—Bartlett pears used in this experiment had a pressure test of 18½ pounds when harvested and a color rating of approximately 2. A gas mixture series identical with that shown for Santa Rosa plums also was used in the Bartlett pear study. At 40 degrees F all lots were in excellent condition following the 10-day treatment and color had changed very little. There was a retardation in color development and in ripening in CO_2 concentrations of 25, 40 and 60 per cent,

TABLE III—SANTA ROSA PLUMS: COLOR DEVELOPMENT AND CONDITIONS AFTER 10 DAYS AT 40 DEGREES AND AT 65 DEGREES F WHEN HELD IN ATMOSPHERES SHOWN (FRUIT HARVESTED JULY 9, 1946. WEIGHT OF SAMPLES APPROXIMATELY 1180 GRAMS—20 FRUITS. DATA IN THE OXYGEN SERIES REPRESENTS THE AVERAGE OF TWO LOTS)

Lot No.	Atmosphere		Numerical Color			Percentage Decay			Remarks—When Ripe
	Per Cent O_2	Per Cent CO_2	Jul 19	Jul 23	Jul 27	Jul 19	Jul 23	Jul 27	
				Oxygen Series at 40 Degrees F					
1	2.5	0	4.4	5.4	7.4	0	0	0	Normal color and flavor
2	5.0	0	4.4	6.0	7.5	0	0	0	Normal color and flavor
3	10.0	0	4.0	5.8	7.5	0	0	0	Normal color and flavor
4	15.0	0	4.2	5.7	7.3	0	0	2.5	Normal color and flavor
5	21.0	0	4.4	5.8	8.3	0	0	0	Normal color and flavor
				Carbon Dioxide Series at 40 Degrees F					
6	20.5	2.5	4.5	6.0	7.4	0	0	0	Normal color and flavor
7	20.0	5.0	4.4	5.7	7.1	0	0	0	Normal color and flavor
8	19.0	10.0	4.6	5.3	7.2	0	0	0	Normal color and flavor
9	18.0	15.0	4.3	5.7	7.0	0	0	0	Normal color and flavor
10	16.0	25.0	4.3	5.6	6.7	0	0	0	Normal color and flavor
11	12.5	40.0	4.4	5.5	7.0	0	0	0	Normal color and flavor
12	8.0	60.0	4.1	5.3	7.2	0	0	0	Flavor and flesh color normal but slight CO_2 injury
				Oxygen Series at 65 Degrees F					
13	2.5	0	4.8	5.8	7.9	2.5	5.0	5.0	More acid than air lot
14	5.0	0	6.6	7.8	9.3	0	0	7.5	Normal color and flavor
15	10.0	0	7.5	8.6	9.7	10.0	10.0	17.5	Normal color and flavor
16	15.0	0	7.4	8.7	9.6	10.0	10.0	40.0	Normal color and flavor
17	21.0	0	7.5	9.0	9.5	0	0	25.0	Normal color and flavor
				Carbon Dioxide Series at 65 Degrees F					
18	20.5	2.5	7.5	8.6	9.0	0	0	5	Normal color and flavor
19	20.0	5.0	6.9	8.1	8.8	0	0	5	Normal color and flavor
20	19.0	10.0	6.7	8.1	8.6	0	0	0	Normal color and flavor
21	18.0	15.0	6.0	7.7	8.9	0	0	0	Normal color and flavor
22	16.0	25.0	5.2	6.2	7.6	0	0	0	Normal color and flavor
23	12.5	40.0	4.6	5.6	7.5	0	0	5	Flavor slightly abnormal Flesh failed to develop Normal red color
24	8.0	60.0	4.4	5.4	6.2	0	0	0	

but all fruits ripened satisfactorily. There was some indication that the 2.5 and 5 per cent oxygen lots developed better flavor than others.

As anticipated from previous trials (1) pears held at 65 degrees F in the different gas mixtures varied greatly in ripeness at the end of 10 days. The 2.5 and 5 per cent O_2 and all of the CO_2 lots except 2.5 per cent were still in suitable condition to be acceptable by the wholesaler, having a color rating of 2.7 or less in comparison to the air lot color rating of approximately 4.5. Fruits from all of these lots ripened satisfactorily except those held in 40 and 60 per cent CO_2 which remained slightly hard or woody in texture. The 65 degrees F lots which arrived in green enough condition to be acceptable for marketing, remained salable fully as long as those fruits which had been held at 40 degrees F.

Primrose Peaches:—This variety of peach while not commercially important is a good flavored, firm fleshed freestone peach. When held at 40 degrees F for 10 days, all lots were in good marketable condition as shown in Table IV. Ripening of the 25 and 40 per cent CO_2 lots was retarded in comparison to fruits held in air. At 65 degrees the

TABLE IV—PRIMROSE PEACHES: COLOR DEVELOPMENT AFTER 10 DAYS AT 40 DEGREES AND AT 65 DEGREES F WHEN HELD IN ATMOSPHERES SHOWN (FRUIT HARVESTED JULY 22, 1946; WEIGHT OF SAMPLES APPROXIMATELY 1320 GRAMS—9 FRUITS; OXYGEN SERIES IS AVERAGE OF TWO LOTS PER TREATMENT)

Lot No.	Atmosphere		Numerical Color			
	Per Cent O_2	Per Cent CO_2	40 Degree F Lots		65 Degree F Lots	
			Aug 2	Aug 7	Aug 2	Aug 7
			Oxygen Series			
1	2.5	0	4.0	7.6	3.4*	7.0
2	5.0	0	4.5	7.1	5.5*	8.0
3	10.0	0	4.3	7.2	6.0*	8.2
4	15.0	0	4.5	7.7	6.7*	8.6
5	21.0	0	4.1	7.0	6.9*	8.7
			Carbon Dioxide Series			
6	20.5	2.5	4.6	6.7	7.0	8.7
7	20.0	5.0	4.2	6.9	7.1	8.6
8	19.0	10.0	3.9	6.3	6.7	8.3
9	18.0	15.0	—	—	6.5	8.3
10	16.0	25.0	3.1	5.7	All fruits badly injured. Color sickly green, skin sloughs off; very bad flavor	
11	12.5	40.0	3.3	5.8		
12	8.0	60.0	4.2	6.9	Severe injury but less than at 25 and 40 per cent CO_2.	

*Observations made August 1.

sample held in 2.5 per cent oxygen remained as green during the transit period as the lots held at 40 degrees and the fruit continued its ripening processes without the development of abnormal flavors. The high CO_2 concentrations were lethal, causing the flesh to be discolored, and of a bad odor, and the skin to slough off much as would be the case with an immature potato.

Grapes:—The principal problems involved in table grape shipments are (a) discoloration of the stems, (b) decay and (c) shatter. The latter affects primarily the Thompson seedless variety. California grapes are usually fumigated with SO_2 gas prior to shipment, in order to reduce browning of the stems and delay the growth of decay organisms in transit. In the first test with Thompson Seedless and the second with Tokay, the fruits were not treated with SO_2 gas. However, sufficient promise in reducing decay and maintaining a good appearance of the fruit and stems, was shown from high CO_2 concentrations that a third test was made, this time using SO_2 gas as in commercial practice, prior to placing the fruits in modified atmospheres. This last test was set up late in the season when the condition of the grapes would have made commercial shipment problematical. Grapes placed in modified atmospheres were all held at 65 degrees F, but were compared with air lots at 45 degrees F.

As shown in Table V none of the lots in the oxygen series were as good as the 45 degrees F air lot which corresponds to present shipping practice under refrigeration. The stem condition of the fruits in lot 1 held in the 1 per cent oxygen was very good but the per cent of decayed berries was beyond the shipping tolerance. All other lots in the oxygen series developed some mold on the stems as well as superficial mold growth at the stilar end of many berries.

The grapes in the CO_2 series held in concentrations up to 15 per cent CO_2 were generally not in as good condition as the 45 degrees F air lots. There was some mold growth on the small stems and enough decayed berries to make commercial application unlikely. However, when the CO_2 concentration was increased to 25 per cent or above no mold growth occurred on the stems and berry decay was held to a low level. Berries in these lots had an excellent bright appearance.

The excessive amount of decay in some lots such as 3 and 15 is probably the result of small samples, as most of the decayed berries were in a single bunch in these lots.

TABLE V—TOKAY GRAPES: CONDITION AFTER 10 DAYS AT 65 DEGREES F IN ATMOSPHERES SHOWN (FRUIT HARVESTED OCTOBER 15, 1946 AND FUMIGATED FOR 23 MINUTES IN 2 PER CENT GAS; WEIGHT OF SAMPLES APPROXIMATELY 1250 GRAMS, ABOUT 225 BERRIES)

Lot No.	Atmosphere		Berries		Stems
	Per Cent O_2	Per Cent CO_2	Decay Per Cent	General Appearance	General Condition
			Oxygen Series		
1	1.0	0	3.6	Good	Good—green and free from mold
2	2.5	0	2.2	Fair	Fair—green, slight mold on small stems
3	5.0	0	5.3	Poor to fair	Fair—mostly green, mold on small stems
4	10.0	0	1.9	Fair	Fair—green, slight mold on small stems, capstems rather dry
5	15.0	0	2.9	Fair	Fair—green to brown, small stems dry with some mold
6	21.0	0	3.8	Fair	Poor to fair—mostly brown, some mold, capstems dry
7*	21.0	0	0.0	Very good	Good—green
			Carbon Dioxide Series		
8	20.0	5.0	1.7	Good	Fair—mostly green, slight mold on small stems
9	19.0	10.0	2.3	Good	Good—green
10	18.0	15.0	2.8	Good	Fair—green to greenish brown, slight mold on small stems, capstems fairly dry
11	16.0	25.0	0.0	Very good	Good—green, no mold
12	12.5	40.0	1.2	Very good	Good—mostly green, capstems fairly dry
13	8.0	60.0	0.0	Very good	Good—mostly green, capstems fairly dry
			Low Oxygen, Plus Carbon Dioxide Series		
14	2.5	5.0	0.6	Good	Good—green, some capstems brownish and moderately dry
15	2.5	10.0	7.1	Poor	Good—greenish, capstems fairly dry
16	2.5	15.0	1.4	Good	Fair—mostly green, some capstems dry with mold
17	2.5	25.0	1.7	Very good	Good—green to light brown, capstems fairly dry
18	2.5	40.0	0.9	Very good	Good—fairly green, capstems slightly dry

*Held at 45 degrees F for the 10-day period.

DISCUSSION

It has long been recognized that the rate of a chemical reaction may be modified by (a) temperature, (b) supply of material entering into reaction and (c) the accumulation of end products of the reaction. Refrigeration has been used as the commercial means of reducing the rate of metabolic activity of fruits in transit to market. Although numerous investigators have recently reported on the benefits to be derived from the addition of CO_2 to cars of fruits and vegetables in transit or prior to transit, these treatments have been considered as supplemental to refrigeration.

It does not seem unreasonable to suggest that modified atmospheres may supplant refrigeration for slowing up metabolic processes during the movement of certain fruits and, perhaps vegetables, across the country.

In the experiments reported here, promising results were obtained at 65 degrees F with low oxygen on plums, pears and peaches and with high CO_2 on plums, pears and grapes. Undoubtedly the metabolic processes of fruits are so complicated that neither low O_2 nor high CO_2 is a satisfactory method of slowing up the whole chain of reactions involved in respiration. This is evidenced by the development of off flavors, failure to soften properly or a complete breakdown of tissues before passing through the normal ripening stages, as found in some of the treatments in these tests, and shown in reports of other investigators. However, with the resumption of pre-war perishable freight schedules or proposed schedules of 1 to 2 days shorter than pre-war and improvements in new car construction, the possibility of shipping certain fruits across the continent in modified atmospheres without refrigeration seems promising. Certain vegetable crops, especially those subject to chilling injury, might also have possibilities of shipment in this manner.

Additional studies are needed involving both other fruits and higher temperatures. Transit studies to determine temperatures that would be encountered by precooled and non-precooled fruit would be helpful in simulating transit tests. Perhaps of greatest importance would be information regarding the products of respiration other than CO_2 at different temperatures and under different modified atmospheres.

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Peach Storage in Modified Atmospheres[1]

By H. J. O'Reilly, *Cornell University, Ithaca, N. Y.*

PEACHES when placed in cold storage immediately after harvest for periods exceeding 1 to 2 weeks have been found to lose their flavor and to develop a dry, mealy type of internal breakdown (1). This short storage life is a factor of considerable commercial importance wherever peaches are grown and marketed. Deterioration of quality in storage is associated with an apparent loss of juiciness of the flesh, which has been described in South Africa by Davies *et al.* (1) in 1936, as being a dry mealy condition with a flat objectionable flavor. Tindale (14) in 1930 has also mentioned a mealy type of breakdown occurring on cold storage of Australian peaches and since that time other reports of mealiness (or "woolliness") have appeared (1, 2, 3, 4, 5, 6, 7, 8, 10, 13). Davies *et al.* (2) in 1937 observed that a period of delay before storage of from 1 to 3 days at a warm temperature was an important factor with regard to avoiding the onset of mealiness during storage. Where the initial delayed period was at a higher temperature, the required duration of delay was found to be less. The rate at which fruit was cooled on placing it in cold storage did not appear to be of importance. The same workers in 1938 (3) noted that a delay of 2½ to 3 days at 75 degrees F followed by 25 days at 34 degrees F eliminated all but a trace of mealiness in the variety Peregrine.

Fisher and Britton (5) found that a pre-storage delay of 1 to 2 days at 75 degrees F did not reduce storage life of Rochester and Valiant and both quality and texture were improved through elimination of mealiness. Fisher *et al.* (6) delayed the storage of their fruit at a temperature of about 75 degrees F until pressure readings on the unpared fruit surface indicated 10 pounds on a $^{7}/_{16}$ inch point at which time it was stored at 32 degrees F. With a 1 to 2 day delay, mid-season varieties such as Rochester and Vedette had an extended safe storage life of 1 to 2 weeks over non-delayed fruit. With the later varieties Hale and Elberta a delay of 2 to 5 days also extended storage life by a week but with these late varieties Fisher *et al.* (6) reported continual storage at 65 degrees F was as effective as a delay of 2 to 5 days at 75 degrees F followed by storage at 32 degrees F.

Haller and Harding's work (8) showed less mealiness and breakdown to occur at storage temperatures of 30 to 32 degrees F than at higher temperatures of 36 to 50 degrees F. This is also borne out by other workers (1, 2, 3, 5, 6, 7, 14, 15). Haller and Harding (8) associated this increase in mealiness and breakdown at higher storage temperatures with a possible upset of the normal fruit metabolism followed by an abnormal type of ripening. Morris (12) however reported that Early Crawford, Elberta and J. H. Hale kept in a good condition for a longer period at 40 to 50 degrees F than at 32 degrees F.

Davies and Boyes (4) treated Elberta peaches with 1 per cent acetylene gas at 75 degrees F for 24 hours to hasten the respirational climacteric. After this treatment the fruit was delayed in air for an additional 4 days at 75 degrees F. On removal from storage at 34 degrees F 24 days later no mealiness or appreciable loss of flavor could be detected.

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[1] This work was made possible through a grant from Mr. Frank Field Chase of Encinitas, California.

Hall (7) using the varieties J. H. Hale, Phillips Cling, and Golden Queen found that quality for canning was still satisfactory after 3 weeks at 30 to 32 degrees F if preceded by a 24-hour delay. When a similar delay and duration of storage were used but held in modified storage atmosphere of (a) 5 per cent carbon dioxide, 16 per cent oxygen, and (b) 10 per cent carbon dioxide with 11 per cent oxygen, off flavors resulted. Huelin and Tindale (9) reported that atmospheres of 8 to 10 per cent carbon dioxide and 11 to 13 per cent oxygen at 32 degrees F produced an extended storage life in Catherine Anne peaches only where the initial pressure or firmness at picking was 15 pounds or more using a pressure tester fitted with a $^5/_{16}$-inch point.

Fisher *et al.* (6) held J. H. Hale at 32 degrees F in atmospheres containing 7 and 9 per cent carbon dioxide obtained by reduced ventilation. Their findings indicated that such a treatment did not lengthen storage life over that of fruit placed in air at 32 degrees F.

This investigation was undertaken to study the interrelation of maturity of the fruit at harvest, delayed storage, and storage in modified atmospheres on subsequent quality and storage life.

MATERIALS AND METHODS

Six modified atmospheres were used at both 32 degrees and 40 degrees F with gas tight containers of 45-gallon capacity serving as modified atmosphere chambers. After sealing the fruit within the chambers, the atmospheres were built up by displacing the internal air with nitrogen and then introducing approximately the desired amounts of carbon dioxide and oxygen. Gas analyses were at once carried out and adjustments made to the atmosphere desired. Internal atmospheres were analyzed and corrected at least every other day throughout the experiment. In general, variations did not exceed 1 per cent. The atmospheres used at both 32 degrees F and 40 degrees F were composed of the combinations of carbon dioxide and oxygen indicated in Table I.

The four varieties in the experiment ranged in season from early to late (Cumberland, Golden Jubilee, Halehaven and Elberta). Modified atmosphere combinations 5 and 6 were not used for Elberta as they

TABLE I—MODIFIED ATMOSPHERES IN WHICH PEACHES WERE STORED AT BOTH 32 DEGREES F AND 40 DEGREES F

Number	Carbon Dioxide	Oxygen
1	2	2
2	2	5
3	5	2
4	10	2
5	10	5
6	10	11
7	0	21 (air)

had appeared undesirable for the other varieties. At picking time each variety was arbitrarily segregated into two degrees of ripeness (a) immature and (b) mature, the two classes being differentiated by color of skin and pressure test. All varieties but the Elberta were grown in the Cornell University orchard. The Elberta was obtained from a commercial orchard near Ithaca, New York.

On separating each variety into two degrees of maturity, half of each sample was placed in storage at once and the modified atmospheres made up. The remaining lots were delayed for periods of 2 to 5 days on the packing house floor at the temperatures prevailing of approximately 75 degrees ± 5 degrees F. The duration of delay varied according to the initial maturity, and rate of ripening of the fruit. Except in the Cumberland variety where insufficient fruit was available, a peck constituted each individual treatment.

Skin color was recorded at harvest and again on ripening after removal from storage, using Maerz and Paul's Dictionary of Color (11) as a standard. Pressure tests were made on the peeled fruit surface, taking the average of eight fruits. A Magness-Taylor pressure tester was used fitted with a $^{7}/_{16}$ inch point. Soluble solid determinations were obtained with a portable Zeiss refractometer.

Table II presents data giving skin color, firmness and soluble solids of both the immature and mature fruit at harvest time.

The data in Table II indicate that all immature fruits possessed various shades of green and were very firm. The mature Halehaven was somewhat softer and comparatively more ripe than the mature fruits of the other varieties. Soluble solid differences were small but showed a slightly higher reading in the later varieties.

TABLE II—SKIN COLOR, FIRMNESS AND SOLUBLE SOLIDS AT HARVEST

Variety	Harvest Date	Skin Color*	Firmness Pounds†	Soluble Solids (Per Cent)
		Immature Fruit		
Cumberland	Aug 16	Russet Green Plate 20 1-K	30.0	8.3
Golden Jubilee	Aug 19	———— Plate 17 3-J	29.0	9.0
Halehaven	Aug 31	Charteuse Plate 11 1-L	26.0	9.8
Elberta	Sep 16	Sea Green Plate 19 6-K	30.0	9.8
		Mature Fruit		
Cumberland	Aug 16	Citron Green Plate 19 2-K	25.0	9.0
Golden Jubilee	Aug 19	Amber Yellow Plate 10 3-J	16.5	9.1
Halehaven	Aug 31	Wax Yellow Plate 11 4-L	24.0	10.2
Elberta	Sep 16	Javel Green Plate 19 2-L	28.0	10.0

*Maerz and Paul "Dictionary of Color".
†On peeled surface using 7/16 inch point with Magness-Taylor pressure tester.

Storage Treatments: Table III presents the duration of storage at 32 and 40 degrees F in the six modified atmospheres and in air, as well as the length of delay at 75 degrees ± 5 degrees F prior to storage in the "delayed storage" treatments.

RESULTS

The response to the modified atmosphere storage treatments obtained from the variety Golden Jubilee may be taken as representative

TABLE III—DURATION OF STORAGE

Variety	Immature, Days Delay	Mature, Days Delay	Days at 32 Degrees or 40 Degrees F	Total Days
Delayed Storage Treatment				
Cumberland	5	–	20	25
Cumberland	–	2	23	25
Golden Jubilee	3	–	19	22
Golden Jubilee	–	2	20	22
Halehaven	4	–	12	16
Halehaven	–	3	13	16
Elberta	3	–	18	21
Elberta	–	2	19	21
Immediate Storage Treatment				
Cumberland	–	–	25	25
Golden Jubilee	–	–	22	22
Halehaven	–	–	16	16
Elberta	–	–	21	21

of the four varieties tested in this study. Tables IV and V present details of the condition of the fruit on ripening after removal from the six modified atmospheres at temperatures of both 32 degrees F and 40 degrees F. The more favorable temperature appeared to be 32

TABLE IV—FRUIT QUALITY AFTER RIPENING ON REMOVAL FROM 22 DAYS STORAGE AT 32 DEGREES F (VARIETY GOLDEN JUBILEE)

Atmosphere		Treatment	Days to Ripen at 75 Degrees F	Texture and Flavor
CO_2 Per Cent	O_2 Per Cent			
2	2	Mature—delay*	1	Juicy, flavor flat
2	2	Mature—immediate†	2	Becoming mealy, flavor flat
2	2	Immature—delay*	2	Juicy, flavor fair
2	2	Immature—immediate†	3	Becoming mealy, flavor flat
2	5	Mature—delay	1	Juicy, flavor flat
2	5	Mature—immediate	3	Becoming mealy, flavor fair
2	5	Immature—delay	2	Juicy, flavor fair
2	5	Immature—immediate	4	Becoming mealy, flavor flat
5	2	Mature—delay	2	Juicy, flavor good
5	2	Mature—immediate	3	Becoming mealy, flavor flat
5	2	Immature—delay	3	Juicy, flavor flat
5	2	Immature—immediate	3	Becoming mealy, flavor flat
10	2	Mature—delay	1	Juicy, off flavor
10	2	Mature—immediate	2	Juicy, slightly off flavor
10	2	Immature—delay	2	Juicy, flavor flat
10	2	Immature—immediate	3	Mealy, off flavor
10	5	Mature—delay	0	Juicy, off flavor
10	5	Mature—immediate	2	Juicy, slightly off flavor
10	5	Immature—delay	2	Juicy, off flavor
10	5	Immature—immediate	3	Mealy, off flavor
10	11	Mature—delay	0	Juicy, off flavor
10	11	Mature—immediate	1	Juicy, off flavor
10	11	Immature—delay	2	Juicy, off flavor
10	11	Immature—immediate	3	Mealy, breakdown, off flavor
Air Check		Mature—delay	0	Juicy, flavor fair
Air Check		Mature—immediate	2	Mealy breakdown, flavor flat
Air Check		Immature—delay	1	Juicy, flavor flat
Air Check		Immature—immediate	3	Mealy breakdown, flavor flat

*Delayed at 75 degrees ± 5 degrees F before storage for 2 days with mature fruit and 3 days with immature fruit.

†Placed in cold storage at once without a delay.

TABLE V—Fruit Quality After Ripening on Removal from 22 Days Storage at 40 Degrees F (Variety Golden Jubilee)

Atmosphere		Treatment	Days to Ripen at 75 Degrees F	Texture and Flavor
CO_2 Per Cent	O_2 Per Cent			
2	2	Mature—delay*	0	Becoming mealy, over-ripe, flavor flat
2	2	Mature—immediate†	2	Mealy breakdown, flavor flat
2	2	Immature—delay*	2	Becoming mealy, flavor flat
2	2	Immature—immediate†	3	Mealy breakdown, flavor flat
2	5	Mature—delay	0	Mealy over-ripe, flavor flat
2	5	Mature—immediate	1	Mealy breakdown, flavor flat
2	5	Immature—delay	2	Becoming mealy, flavor flat
2	5	Immature—immediate	2	Mealy breakdown, flavor flat
5	2	Mature—delay	1	Juicy, flavor fair to good
5	2	Mature—immediate	2	Mealy breakdown, flavor flat
5	2	Immature—delay	2	Becoming mealy, flavor flat
5	2	Immature—immediate	2	Mealy breakdown, flavor flat
10	2	Mature—delay	1	Becoming mealy, flavor flat
10	2	Mature—immediate	2	Mealy breakdown, flavor flat
10	2	Immature—delay	2	Mealy breakdown, off flavor
10	2	Immature—immediate	3	Mealy breakdown, off flavor
10	5	Mature—delay	0	Juicy, over-ripe, flavor fair
10	5	Mature—immediate	1	Becoming mealy, flavor flat
10	5	Immature—delay	1	Juicy, off flavor
10	5	Immature—immediate	2	Mealy breakdown, off flavor
10	11	Mature—delay	0	Becoming mealy, over-ripe, off flavor
10	11	Mature—immediate	1	Mealy breakdown, off flavor
10	11	Immature—delay	2	Becoming mealy, off flavor
10	11	Immature—immediate	3	Mealy breakdown, off flavor
Air	Check	Mature—delay	0	Becoming mealy, over-ripe, flavor flat
Air	Check	Mature—immediate	1	Mealy breakdown, flavor flat
Air	Check	Immature—delay	1	Becoming mealy, flavor flat
Air	Check	Immature—immediate	2	Mealy breakdown, flavor flat

*Delayed at 75 degrees F before storage for 2 days for mature fruit and 3 days for immature fruit.
†Placed in cold storage at once without a delay.

degree F for both modified atmosphere storage and air storage, as all treatments held at 40 degrees F were of relatively poorer quality. Tables IV and V suggest that an improved flavor and texture were obtained more often from the mature lots than from the immature lots. Where mature fruit had been delayed at 75 degrees ± 5 degrees F, the best quality was noted. Other treatments especially immature fruit stored without a delay were removed in a dry mealy condition and internal breakdown followed instead of normal ripening. Some modified atmospheres were more beneficial than others. The levels (a) 2 per cent carbon dioxide with 2 per cent oxygen, (b) 2 per cent carbon dioxide with 5 per cent oxygen and (c) 5 per cent carbon dioxide with 2 per cent oxygen appeared to give the most favorable results. In those atmospheres containing 10 per cent carbon dioxide a distinct off flavor was noted. The air check often lacked quality in both flavor and texture of the flesh but no off flavors were detected.

A comparison of Table IV and V suggests that better quality fruit resulted from the mature, delayed treatments when held at the lower storage temperature of 32 degrees F as shown in Table IV. This group of treatments for all four varieties is summarized in Table VI in order to compare the six modified atmospheres used throughout. As in Tables IV and V it can be seen that where neither carbon dioxide nor oxygen exceeded 5 per cent of the storage atmosphere, that the off

TABLE VI—QUALITY OF MATURE-DELAYED TREATMENTS IN SIX MODIFIED ATMOSPHERES AT 32 DEGREES F*

Atmosphere		Days to Ripen at 75 Degrees F	Texture and Flavor
CO_2 Per Cent	O_2 Per Cent		
		Cumberland	
2	2	2	Juicy, flavor good
2	5	2	Juicy, flavor good
5	2	2	Juicy, flavor good
10	2	1	Juicy, off flavor
10	5	2	Juicy, off flavor
10	11	1	Juicy, off flavor
Air	Check	1	Juicy, flavor flat
		Golden Jubilee	
2	2	1	Juicy, flavor flat
2	5	1	Juicy, flavor flat
5	2	2	Juicy, flavor good
10	2	1	Juicy, off flavor
10	5	0	Juicy, off flavor
10	11	0	Juicy, off flavor
Air	Check	0	Juicy, flavor fair
		Halehaven	
2	2	0	Juicy, slightly flat
2	5	1	Juicy, flavor good
5	2	1	Juicy, flavor good
10	2	0	Juicy, off flavor
10	5	0	Juicy, off flavor
10	11	0	Juicy, off flavor
Air	Check	0	Juicy, flavor flat
		Elberta	
2	2	2	Juicy, flavor good
2	5	2	Juicy, flavor flat
5	2	2	Juicy, flavor flat
10	2	3	Juicy, off flavor
Air	Check	2	Becoming mealy, flavor flat

*Delayed at 75 degrees ± 5 degrees F before storage 2 days for Cumberland, Golden Jubilee, and Elberta and 3 days for Halehaven.

TABLE VII—SKIN COLOR, FIRMNESS AND SOLUBLE SOLIDS OF TREATMENTS HAVING "GOOD" QUALITY ON REMOVAL FROM STORAGE AT 32 DEGREES F

Atmosphere		Skin Color	Firmness (Lbs)	Soluble Solids
CO_2 Per cent	O_2 Per cent			
		Cumberland		
2	2	Chartreuse Plate 11 1-L	10.6	10.1
2	5	Pyrethrum yellow Plate 11 2-L	9.1	9.9
5	2	Acacia Plate 11 1-K	10.0	9.3
Air	Check	Acacia Plate 11 1-K	9.0	9.5
		Golden Jubilee		
5	2	Chinese yellow Plate 10 6-K	10.1	9.7
Air	Check	Golden rod Plate 10 5-L	9.8	9.5
		Halehaven		
2	5	Aureolin Plate 10 2-L	10.2	11.3
5	2	Citron yellow Plate 10 2-J	10.3	10.8
Air	Check	Lemon yellow Plate 10 3-K	10.0	10.9
		Elberta		
2	2	Amber yellow Plate 10 3-J	9.1	10.3
Air	Check	Aureolin Plate 10 2-L	8.9	10.5

flavors noted in those atmospheres containing 10 per cent carbon dioxide did not occur.

Table VII summarizes readings taken for pressure test, color and soluble solids obtained on ripening after removal from storage of those treatments which were of "good" quality as indicated in Table VI. The corresponding check treatments in air are also shown.

In Table VII it is indicated that on removal from storage and after ripening, skin color ranged through varying shades of warm yellow, firmness of the flesh was about 9 to 10 pounds, and soluble solids varied from 9 to 11 per cent.

SUMMARY

1. 32 degrees F appeared to be a more suitable temperature than 40 degrees F at which to store peaches both in air and modified atmospheres.
2. A delay of 2 to 5 days prior to cold storage was required to prevent the onset of a mealy type of storage breakdown. The necessary period of delay varied with the maturity at which the fruit was harvested.
3. Even mature fruit at harvest was less likely to develop mealy breakdown when placed in cold storage after a suitable delay at 75 degrees ± 5 degrees F.
4. The lower levels of carbon dioxide and oxygen (that is 2 per cent carbon dioxide 2 per cent oxygen, 2 per cent carbon dioxide 5 per cent oxygen, and 5 per cent carbon dioxide 2 per cent oxygen) when used as storage atmospheres appeared more satisfactory than atmospheres containing 10 per cent carbon dioxide. At this concentration off flavors occurred in the fruit.
5. Fruit stored in modified atmospheres preceded by a suitable delay did not have an appreciably longer storage life than that of corresponding delayed lots held in air.

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Quality in Citrus Fruits: Seasonal Changes in Relation to Consumer Acceptance of Oranges, Grapefruit, Temple Oranges, and Tangerines.

By PAUL L. HARDING, *U. S. Department of Agriculture, Orlando, Fla.*

THE importance of citrus fruits in the diet of the nation is indicated by the rapid growth of the citrus industry. During the decade from 1935 to 1945 production of oranges in the United States increased from 52 million boxes to 105 million boxes and of grapefruit from 18 million to 63 million boxes. This tremendous rise in production has been accompanied by an ever-increasing demand for citrus fruits by consumers, from 39 pounds per capita in 1934 to 68 pounds in 1944. Rapid transportation to marketing centers, usually under refrigeration, has contributed to the increasingly wider use of citrus by the consuming public. The many improvements made in handling methods that have resulted in a better retention of vitamins, and the development of higher quality in processed and canned products have also been factors.

Orange and grapefruit juices are important in the diet since they are foods in which the alkaline element ultimately predominates. This is of interest because citrus juice contains organic acids, chiefly citric acid. But the juice is also rich in mineral salts which are predominantly alkaline. The organic acids are destroyed in the process of digestion, so that the final effect of the juice is determined by its mineral content.

It is important that all possible information bearing on those factors that make for higher quality in citrus fruits should be identified and evaluated. With this objective, investigations have been made on oranges, grapefruit, tangerines, and Temple oranges at the U. S. Department of Agriculture Horticultural Field Laboratory, Orlando, Florida.

These investigations have included detailed observations and measurements of the physical characteristics and also analyses of the chemical constituents of the principal varieties of fruits at definite intervals, beginning with immature fruit and continuing until the fruit was fully mature and ripe. The changes that occurred, step by step, were determined; and of more importance, methods for evaluation and establishing definite standards for comparison of these changes were devised.

The ripening process of oranges and grapefruit can take place only while the fruits are attached to the tree. It is therefore obvious that these fruits should not be harvested until they are mature and hence ripe. The following definitions are given in order to avoid possible confusion as to the meaning of the terms "maturity" and "ripening" as they are used here. *Maturity* refers to the stage development of the fruit; *ripening* refers to the process by which a mature fruit becomes edible. A mature fruit is one that has attained such a stage of development that it will ripen with acceptable eating quality. Fruits with starch reserves, such as apples and pears, may be mature at harvest time, but many varieties do not become ripe and edible until sometime later, when they attain their soft, juicy, aromatic qualities. In contrast, oranges and grapefruit do not improve in their eating quality after harvest and owe their sweetness to the natural sugar contained when they are picked; they contain practically no starch and do not undergo such marked change in composition as do apples, pears, or bananas after being picked from the tree. Since the ripening processes in oranges and grapefruit occur only while they are on the tree, it can be readily understood that they should not be harvested until they are mature and hence of acceptable quality. Instead of improving in their eating quality after harvest, these fruits tend to lose quality, the rate of loss being correlated with the temperature at which they are held.

In storage studies made on Florida oranges the rate of respiration was determined at temperatures from 32 degrees to 110 degrees F. The material used up in respiration was ascertained from these data. At 32 degrees F sugar was broken down or "respired"; but at 50 degrees to 70 degrees more acid than sugar was used up, or if the sugar was incompletely oxidized, intermediate products such as ethylene or alcohol were formed. At 90 degrees and above the $\frac{CO_2}{O_2}$ ratios indicated that considerable intramolecular respiration was taking place (that is, that the fruit was breaking down its own tissues to obtain required oxygen).

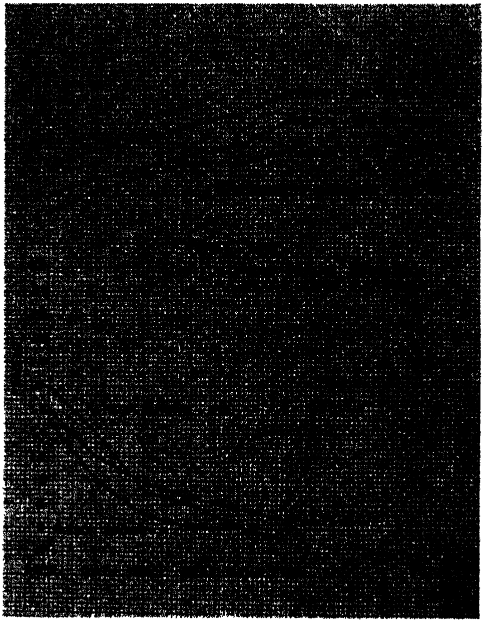

Fig. 1. Seasonal changes in early oranges with indicated date when they were judged mature and would meet consumer acceptance; average for three seasons.

Material and Methods

The data presented in this article were obtained between 1935 and 1946, and these investigations are still in progress. Each type of citrus fruit usually was studied during four consecutive years. The experimental plots were located in several different commercial groves. Variety, rootstock, and soil type determined the selection and location of the plots. Samples were collected from all of the groves at intervals of 2 or 4 weeks, beginning about September 1 and continuing through the season until the fruit was overripe.

This long period of sampling provided information on the changes in physical characters and chemical constituents of the fruit during the various stages of maturity and ripening. Differences among groves, as well as those occurring from year to year, were thus determined. The detailed information is presented elsewhere (1, 2, 3, 4, 5).

Market quality is associated with appearance, firmness, freedom from blemishes, thickness and texture of rind, whereas eating quality is influenced by the texture of flesh, juiciness, content of total solids (principally sugars), total acid (citric), ratio of solids to acid, aromatic constituents, vitamins, and mineral content.

The eating quality of the fruit was determined soon after picking. In each test 30 to 50 or more fruits were used. The fruits were cut transversely and from each half was cut a wedge-shaped piece for tasting. The judging panel was made up of staff members of the Orlando station, and each judge was asked to taste several pieces before rating a sample according to the arbitrary scale. By use of this scale the fruit could be classified as very acid, acid, tart, pleasantly tart to sweet, or insipid. At the beginning of each season the arbitrary standard scale to be used and the method of evaluating internal quality were discussed. At that time it was pointed out that a score of 70 would be the minimum standard of acceptability, whereas good to excellent quality would be rated from 70 to 100. The scale also permitted the scoring of immature fruit (values 20 to 69) and of insipid fruit (values 50 to 100); but it was understood that any rated below 70 would not meet consumer approval and the sweet but insipid fruit would be so designated to differentiate it from better-quality fruit having a similar numerical rating. The judges were believed to represent fairly well the prospective consumers. Tasters showed differences in scoring but not large ones, and the numerical average thus obtained from 20 to 45 judges appears to be a satisfactory method of measuring quality.

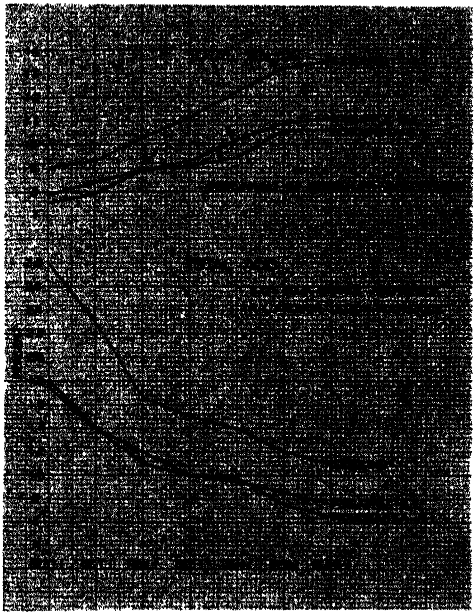

FIG. 2. Seasonal changes in midseason oranges with indicated date when they were judged mature and would meet consumer acceptance; average for three years.

Flavor as determined by taste is closely correlated with seasonal changes in weight and texture of the fruit, the color of its flesh, the percentage of the fruit that is juice, and the ratio of total solids to total acidity. These improve or increase with the maturity of the fruit. By recording the picking dates and plotting the total solids and the total acid in nomograph form (a special chart showing the relation of more than 2 factors), it was possible to show the relation of these two factors to each other in fruit at its earliest stages of consumer acceptance, as judged by its flavor, and eventually to determine a minimum standard of acceptability for the different varieties.

An effort was made to give an over-all picture of the quality of oranges, grapefruit, Temples and tangerines that might be expected on the market at different times. The average values presented for total solids, total acid, and palatability (consumer acceptance) were obtained by averaging the results obtained at each picking period. The results should be regarded as approximate since they are based on average rather than minimum values. These findings are shown in Figs. 1 to 7.

RESULTS

Seasonal Changes in Early Oranges:—Tests were made on several varieties of early oranges; however, in this article only the Hamlin and Parson Brown of the early varieties will be discussed. It will be noted in Fig. 1 that during the development and ripening of the fruits total solids increased, while total acidity decreased. Also in Fig. 1 it may be noted that Hamlin oranges contained lower amounts of solids and greater acidity than Parson Brown fruits.

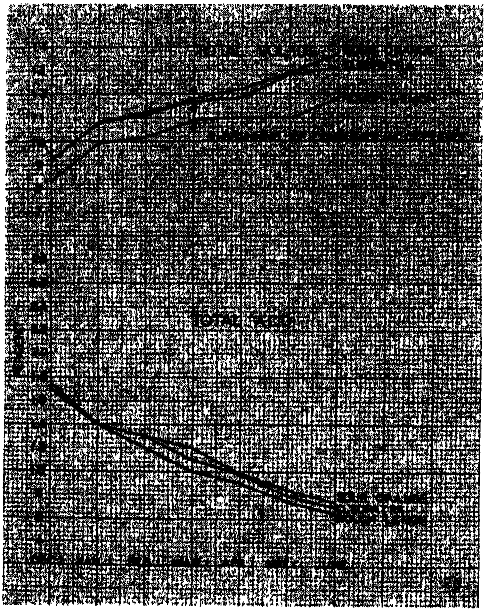

FIG. 3. Seasonal changes in late (Valencia) oranges with indicated date when they were judged mature and would meet consumer acceptance; average for three seasons.

Rough lemon and sour orange rootstocks affected the composition of Parson Brown oranges. On rough lemon they contained a lower percentage of solids and acid than on sour orange.

Parson Browns ripened earlier than Hamlins. They were judged to be of acceptable quality about November 11. At this date those on rough lemon contained 9.35 per cent solids, 0.66 per cent acid, and the ratio of total solids to acid was 14.17 to 1. In comparison, Parson Brown oranges on sour orange rootstock were considered to meet consumer acceptance November 15 and contained 10.60 per cent solids, 0.85 per cent acid, and the ratio was 12.47 to 1. Hamlin oranges on rough lemon were acceptable December 3, when they contained 9.30 per cent solids, 0.85 per cent acid, and the ratio was 10.94 to 1.

Seasonal Changes in Midseason Oranges:—The trends of solids and of acid in midseason oranges were similar to those of the early varieties in that during ripening solids increased and acidity decreased (see Fig. 2). Only small differences existed between the Pineapple and Homosassa varieties but the former contained slightly more solids. Florida Seedlings differed greatly from the two named varieties since they contained very significantly greater amounts of both solids and acid.

The three midseason kinds were rated as acceptable between December 20 and January 25. To be specific, Homosassa oranges were of acceptable quality about December 20 when they contained 9.32 per cent solids, 0.98 per cent acid, and the total solids to acid ratio was 9.51 to 1. Pineapple oranges were acceptable December 28 when they contained 10.12 per cent solids, 0.94 per cent acid, and the ratio was 10.85 to 1. Seedling oranges met consumer acceptance January 25 when they contained 13.07 per cent solids, 1.22 per cent acid, and the ratio was 10.71 to 1.

Seasonal Changes in Late Oranges:—Studies were made to determine the influence of rootstocks on the composition of Valencia oranges. The various plots were in the same grove and consisted of Valencias on rough lemon, sour orange, grapefruit, sweet orange, and Cleopatra rootstocks. Tests were made during three seasons on the Valencias from the plots on rough lemon, sour orange, and Cleopatra, whereas the fruits from the other two plots were tested during two seasons. Seasonal variations were found and these affected some of the averages, especially those made for two seasons only.

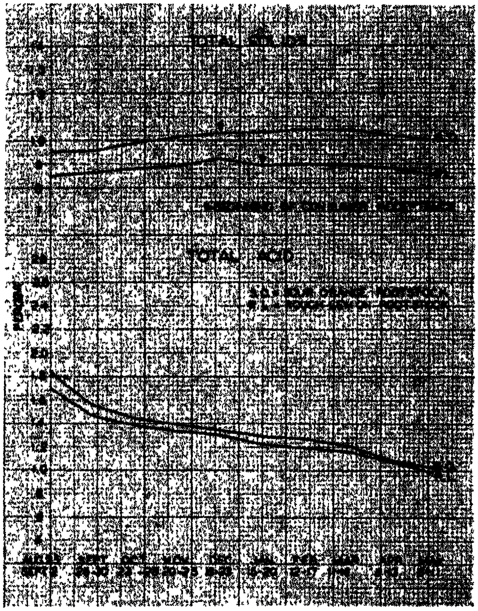

FIG. 4. Seasonal changes in Marsh grapefruit with indicated date when they were judged mature and would meet consumer acceptance; average for four seasons.

The data presented graphically in Fig. 3 show that the Valencias on sour orange and on Cleopatra rootstocks contained a greater percentage of total solids and acid than did those on rough lemon. The total solids produced on grapefruit and on sweet orange were similar to the findings for the Cleopatra rootstock, ranging near those of the sour orange, all being significantly higher than in the case of Valencias on rough lemon stock.

As they ripened the Valencia oranges on all the various rootstocks became less acid. Fruits from the trees on sour orange rootstocks contained the most acid, followed by those from sweet orange, Cleopatra, rough lemon, and grapefruit.

The Valencias on grapefruit rootstock ripened first, being rated acceptable on February 20. At that date they contained 11.07 per cent solids, 1.07 per cent acidity, and the solids-to-acid ratio was 10.35 to 1. The Valencias on the other four stocks were of acceptable quality about March 1. Those on rough lemon contained 10.90 per cent solids, 1.00 per cent acid, and the ratio was 10.90 to 1. On sour orange the solids content was 11.80 per cent, acid 1.20 per cent, and the ratio was 9.83 to 1. Valencias on sweet orange contained 12.00 per cent solids, 1.00 per cent acid, and the ratio was 12.00 to 1. The Valencia fruits on Cleopatra stock contained 11.70 per cent solids, 1.10 per cent acid, and the ratio was 10.64 to 1.

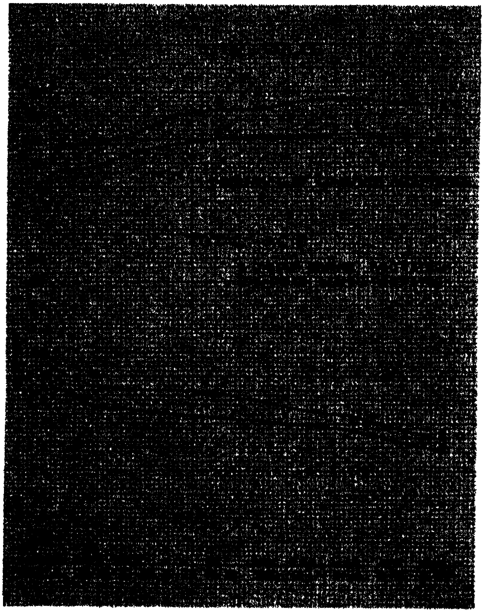

FIG. 5. Seasonal changes in Duncan grapefruit with indicated date when they were judged mature and would meet consumer acceptance; average for four seasons.

Seasonal Changes in Grapefruit: — Investigations were conducted on Marsh and Duncan grapefruit varieties during four seasons. The studies included changes in composition of the fruits, as affected by variety and rootstocks. Figs. 4 and 5 indicate that the changes in total solids and in total acid are more gradual than was the case in oranges. The greatest change appeared early in the season in immature fruit. Total solids content was generally highest when the grapefruit was in prime eating condition, with slightly lower solids earlier in the season in immature fruit and also late in the season in very ripe fruit. The Marsh and Duncan fruits on sour orange rootstock contained a greater amount of total solids than did those on rough lemon. Comparisons between varieties on the same kind of rootstock showed that the Duncan contained higher solids than the Marsh. While there was a downward trend in total acid in both Marsh and Duncan as they ripened, the Duncan was consistently higher in acid than the Marsh. Although total acid was influenced more by variety than by rootstock, the fruit on sour orange was rather consistently higher in acidity than that on rough lemon.

Scores for eating quality showed that both Marsh and Duncan were of acceptable eating quality between December 18 and January 15. Marsh fruits on sour orange were acceptable December 18, when they contained 10.32 per cent solids, 1.33 per cent acid, and the ratio was 7.77 to 1. Duncan fruits met consumer acceptance December 18. Those on rough lemon contained 10.04 per cent solids, 1.45 per cent acid, and the ratio was 6.92 to 1; while Duncan on sour orange contained 11.33 per cent solids, 1.65 per cent acid, and the ratio was 6.87 to 1. Marsh fruits on rough lemon were not of acceptable eating quality until January 15 when they contained 8.91 per cent solids, 1.22 per cent acid, and the ratio was 7.30 to 1.

Seasonal Changes in the Temple Orange:—The Temple orange is notable for its fine eating quality. The fruits contain high total solids and high total acid and are also unique in containing aromatic constituents which impart to flesh and juice an unusually desirable bouquet.

The study on the Temple orange is still in progress, and the information presented herein should thus be regarded as only tentative. Space does not permit a full discussion of all the data accumulated to date; therefore, this article deals only with the compositional changes in the Temple fruits on sour orange rootstock, which is the principal one used for this variety.

Fig. 6 shows the content of total solids and of total acid in Temple oranges during three seasons 1943–44, 1944–45, and 1945–46. The fruits contained slightly higher solids and acid during 1943–44 than during the

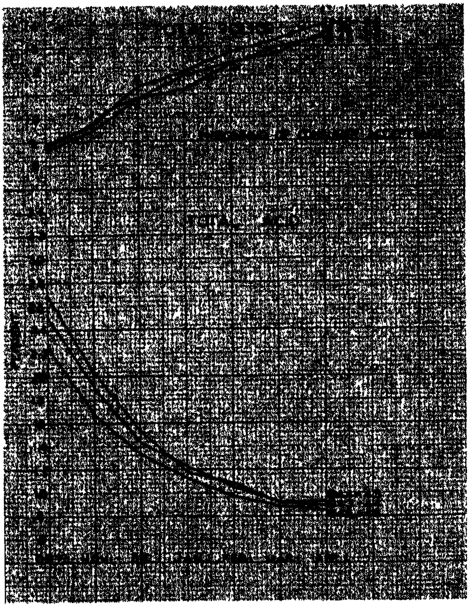

FIG. 6. Yearly variation in Temple oranges on sour orange rootstock with indicated date when they were judged mature and would meet consumer acceptance; average of tests of several groves.

season 1945–46, but the yearly variations were not great.

According to the averages obtained through the taste tests, the Temple was of acceptable eating quality by December 1 of each year. On that date, in 1943, the fruits contained 11.03 per cent total solids, 1.53 per cent total acid, and the ratio of total solids to acid was 7.21 to 1. In 1944 the ripe fruits contained 10.82 per cent solids, 1.43 per cent acid, and the ratio was 7.57 to 1; while in 1945 fruit which met consumer acceptance contained 10.82 per cent solids, 1.33 per cent acid, and the ratio was 8.14 to 1.

Seasonal Changes in Tangerines:—The study of tangerines is also still in progress, and the information here presented should also be regarded as only tentative. The information given is for the Dancy tangerine on rough lemon rootstock, which is the principal variety and the most commonly used rootstock for tangerines.

Yearly variations for tangerines are shown in Fig. 7. It will be seen that there was considerable difference from year to year. The highest amounts of both total solids and total acid were found during the season of 1943–44, and the smallest amount during 1945–46.

Tangerines in 1943 were first rated of acceptable quality about December 1 when they contained 10.96 per cent solids, 1.12 per cent acid, and the ratio of solids to acid was 9.79 to 1. In 1944 tangerines were acceptable November 15 when they contained 9.92 per cent solids, 0.89 per cent acid, and the ratio was 11.15 to 1. The fruits met consumer acceptance November 15, 1945, and then contained 8.96 per cent solids, 0.70 per cent acid, and the solids to acid ratio was 12.80 to 1.

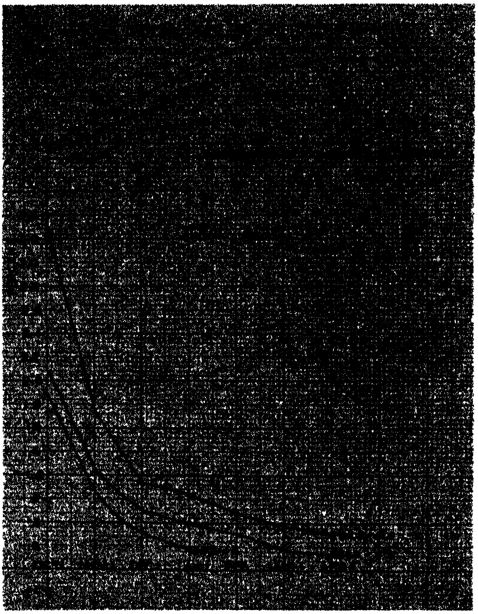

FIG. 7. Yearly variation in tangerines on rough lemon rootstock with indicated date when they were judged mature and would meet consumer acceptance; average of tests of several groves.

SUMMARY

The fruit quality standards arrived at in these investigations resulted from the data obtained through chemical analyses and taste testing by a panel of taste judges.

A statistical study was made of some of the taste ratings of individual judges. It was found that although differences existed among tasters, they were not large. There was a definite association between palatability ratings and some of the more exact measurements, such as total solids, and total acid. Thus the statistical studies indicated that the palatability ratings were quite satisfactory to measure quality.

An over-all picture has been presented of the progress of ripening changes in oranges, grapefruit, Temples, and tangerines, and of the quality that might be expected on the market at different times. The general statements given are based on the averaged results of repeated tests.

The standards of consumer acceptance which were set up by the tasting panel do not agree very closely with the standards in the present maturity laws. The taste judges demanded sweeter and more mature fruit, or, in other words, fruit containing higher ratios of total solids to total acid than that which would pass State maturity requirements. The differences between the standards established through the tasting panel and by the maturity laws were greater for oranges and tangerines than for grapefruit.

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Vitamin C — Nitrogen Relations in Peaches as Influenced by Fertilizer Treatment[1]

By S. H. WITTWER, *Michigan State College, East Lansing, Mich.*, and AUBREY D. HIBBARD, *University of Missouri, Columbia, Mo.*

A DEPRESSION in the vitamin C content of apples by nitrogen fertilizers has been recorded by Bracewell, Hoyle, Wallace, and Zilva (2, 3, 8). Similar results were obtained by Kessler (6). The recent studies of Jones, Van Horn, and Finch (5) indicate that the concentration of ascorbic acid in grapefruit juice bears a marked inverse relation to the nitrogen value. Corresponding relationships have also been found to hold for certain vegetable crops (4, 9). In view of these results and the importance of nitrogen fertilizers in the growing of tree fruits, it was decided to ascertain if a similar correlation between nitrogen and vitamin C held for peaches.

DESCRIPTION OF MATERIALS AND METHODS

The peach orchard used in this study was located in southeastern Missouri, where the soils are classified as belonging to the Loring series. The trees were set 24 feet apart in 1938. There were five trees of a variety under each fertilizer treatment. During the period covered by the present study a winter cover of hairy vetch and small grain was sown about September 1. A stubble mulch type of cultivation was practiced starting June 1, and continuing until seeding time. Tree growth was good and mortality low on all plots except those receiving no fertilizer. No apparent winter injury or frost damage occurred during the period covered by the study.

The season of 1944 was normal during the blooming period but an early summer drought prevailed from the middle of May to the first of July. The seasons of 1945 and 1946 were unusually early, with the blossom dates 15 and 20 days earlier, respectively, than in 1944. Below normal temperatures prevailed during the growing season of 1945 and precipitation was excessive. In 1946 rainfall and temperature were normal.

Vitamin C assays and nitrogen determinations were made on ten carefully matched fruit. The peaches were collected in early morning during the regular harvest season. Only fruit selected from the outer periphery of the five trees in each block were utilized. An attempt was thus made to select peaches of comparable light exposure. The samples were carefully standardized as to maturity by use of the Blake pressure tester and ground color indexes.

In the vitamin C assays, unpeeled fruit was quartered, a section cut from each segment, and the material submitted immediately to analysis. Determinations were conducted according to the dye reduction method of Bessey and King (1). The vitamin concentrations were expressed in milligrams of ascorbic acid per 100 grams of fresh material.

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[1] Missouri College of Agriculture Journal Series No. 1026.

For total nitrogen determinations of the fruit, samples in duplicate of those used in the vitamin C assays were utilized. Leaf samples were collected simultaneously with the fruit. The plant material was carefully dried, ground, and preserved according to standard procedures adopted in the department of horticulture for the preparation of plant material used for chemical analyses. Total nitrogen was determined according to the method outlined by Murneek and Heinze (7), and expressed as percentage of dry weight.

The yields represent the average productive capacity of the trees in each treatment, and included all matured fruit.

Nitrogen fertilizers were added as ammonium sulfate, ammonium nitrate, sodium nitrate, Uramon, and calcium cyanamid (Tables I and II). The basic application was 0.1 pound of actual nitrogen per year of tree growth. Exceptions to this rule were in treatment C, where twice the amount of ammonium sulfate was used, and in treatment B during the 1945 season when three times the normal amount of ammonium nitrate was applied in June. In treatment A an application of phosphorus and potash was put on with the nitrogen. All fertilizers were spaded into the soil as spaced intervals beneath the spread of the branches. This was done during the late winter or early spring with the exceptions of treatments A and E where a split application was used.

During the first year (1944) three varieties, Golden Jubilee, Early Elberta, and Late Elberta were included in the tests. In the two following years only Early and Late Elbertas were considered.

TABLE I—YIELDS AND ASCORBIC ACID-NITROGEN RELATIONS IN PEACHES, AS INFLUENCED BY THE QUANTITY, KIND, AND TIME OF FERTILIZER APPLICATION 1944 SEASON (TREES SEVEN YEARS OLD)

Treatment	Fertilizer Application			Yields and Fruit Composition									Average Nitrogen Content of Leaves All Varieties (Per Cent)
				Golden Jubilee			Early Elberta			Late Elberta			
	Pounds Per Tree	Kind of Fertilizer	Time of Application	Yields Pounds/Tree	Ascorbic Acid Mg/100 gms	Total Nitrogen (Per Cent)	Yields Pounds/Tree	Ascorbic Acid Mg/100 gms	Total Nitrogen (Per Cent)	Yields Pounds/Tree	Ascorbic Acid Mg/100 gms	Total Nitrogen (Per Cent)	
A	13.0	6–10–10	Apr 15	298	6.0	1.10	183	6.3	0.84	268	5.9	0.95	3.02
B	1.75 2.0	Am. Sulphate Nitrate of soda	Apr 15 Jun 20	276	8.3	1.09	204	5.9	1.01	146	5.6	1.35	3.20
C	7.0	Am. Sulphate	Apr 15	258	6.0	1.12	150	6.9	0.95	233	5.4	0.89	3.18
D	3.5	Nitrate of soda	Apr 15	167	7.1	1.20	98	6.9	0.80	133	6.3	1.02	3.16
E	1.75 2.0	Am. Sulphate Nitrate of soda	Apr 15 Aug 20	177	7.3	1.00	209	6.8	0.98	98	6.4	0.92	2.92
F	1.75	Uramon	Apr 15	63	7.5	1.03	66	7.2	0.89	115	7.4	0.83	3.00
G	3.5	Cyanamid	Apr 15	74	9.1	0.83	30	8.4	0.86	72	7.6	0.80	3.19
H	No	Fertilizer	Applied	42	7.7	1.02	29	—	—	93	7.0	0.75	2.92

RESULTS

The yield data, with the vitamin C analyses and the total nitrogen percentages of the fruit and leaves as influenced by fertilizer treatment are presented in Tables I and II. Insofar as possible, treatments are arranged in order of the amount of fruit produced.

TABLE II—YIELDS AND ASCORBIC ACID—NITROGEN RELATIONS IN PEACHES AS INFLUENCED BY THE QUANTITY, KIND, AND TIME OF FERTILIZER APPLICATION

Treatment	Fertilizer Application			Yields and Fruit Composition						Average Nitrogen Content of Leaves (Both Varieties) (Per Cent)
				Early Elberta			Late Elberta			
	Lbs Per Tree	Kind of Fertilizer	Time of Application	Yields Pounds/Tree	Ascorbic Acid Mg/100 Gms	Total Nitrogen (Per Cent)	Yields Pounds/Tree	Ascorbic Acid Mg/100 Gms	Total Nitrogen (Per Cent)	
				1945 Season, Trees Eight Years Old						
A	13	6–9–8	Mar 15	284	6.1	1.12	421	6.3	1.05	3.54
B	2 6	Am. Sulphate Am. Nitrate	Mar 15 Jun 20	281	5.1	1.08	433	5.5	0.92	3.63
C	8	Am. Sulphate	Mar 15	294	5.8	1.09	385	6.0	0.99	3.15
D	2	Am. Nitrate	Mar 15	169	7.4	0.85	364	6.0	1.00	3.09
E	2 2	Am. Sulphate Am. Nitrate	Mar 15 Aug 20	146	6.6	1.10	358	6.4	0.84	3.09
F	2	Uramon	Mar 15	183	6.0	1.00	216	6.9	0.91	2.87
G	4	Cyanamid	Mar 15	161	5.8	0.97	180	6.6	0.88	2.87
H	No	Fertilizer	Applied	94	7.3	0.92	133	11.2	0.73	2.59
				1946 Season, Trees Nine Years Old						
A	14.5	7–9–12	Mar 15	491	6.3	0.74	461	7.6	0.74	2.87
B	2.0	Am. Nitrate	Jun 20	394	5.5	0.76	350	6.3	0.86	3.15
C	9.0	Am. Sulphate	Mar 15	318	6.1	1.09	339	7.0	0.90	2.97
D	3.0	Am. Nitrate	Mar 15	230	7.5	0.95	455	7.0	0.89	2.88
E	2.5 2.0	Am. Sulphate Am. Nitrate	Mar 15 Aug 20	202	7.9	0.71	282	7.1	0.66	2.73
F	2.5	Uramon	Mar 15	222	6.3	0.80	385	5.0	0.78	2.90
G	4.5	Cyanamid	Mar 15	296	6.8	—	343	7.3	0.66	2.66
H	No	Fertilizer	Applied	82	8.3	0.59	95	7.6	0.71	2.27

As yields were increased there was a general depression in the ascorbic acid content of the fruit. An exception was in treatment B where the late June application of nitrogen reduced the vitamin C appreciably, yet failed to increase yields proportionally. The highest overall yields were obtained in treatment A. The higher yields in this case cannot be attributed solely to nitrogen and would indicate that a complete fertilizer was responsible. Even a more outstanding feature with reference to peach quality was that the fruit contained an appreciable greater amount of ascorbic acid. Especially was this the case in the 1946 season, which was the most normal with respect to rainfall of the three years covered by the study.

A tendency toward an inverse correlation between the vitamin C concentration in the fruit and its nitrogen content as well as that of the leaves was noted. However, this was not as clear-cut as has been reported for grapefruit (5) and spinach (9). A large application of readily available nitrogen in late June of 1945 (Table II, treatment B) reduced the ascorbic acid to a low level in the fruit, and augmented the leaf nitrogen, but had little effect on the total nitrogen in the fruit.

The responses from the various nitrogen carriers depended a great deal upon environmental factors associated with the three seasons. In 1944 (Table I) all three varieties receiving the calcium cyanamid and Uramon treatments showed extreme nitrogen deficiencies as evidenced by the appearance of the foliage and nitrogen content of the fruit. Peaches from treatments F and G gave high values for ascorbic acid accompanied by low concentrations of nitrogen. This condition was probably associated with low rainfall and the inability of the trees in these blocks to absorb the slowly available nitrogen. In 1945 and 1946 (Table II) the increased yields from plots F and G were accompanied by a depression in ascorbic acid content of the fruit.

SUMMARY

Results of these experiments clearly indicate that under the environmental conditions peculiar to southeast Missouri a depression in the ascorbic acid content of peaches can be expected when large quantities of nitrogen are applied as fertilizer. It would appear from the data presented herein that readily available nitrogen fertilizers applied in June have a markedly depressing effect upon the concentration of vitamin C in the fruit. A heavy application of ammonium sulfate in early spring has a similar influence. The effects of calcium cyanamid and Uramon vary with the season, giving low yields generally but fruit high in ascorbic acid. An application of complete fertilizer slightly reduced the ascorbic acid in the fruit but gave the highest yields of any treatment.

From the data presented in this report it is apparent that the percentages of total nitrogen in the foliage or fruit of the peach at harvest time, are not always a reliable index of the concentration of ascorbic acid in the fruit.

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Variations in Peach Tree Yields[1]

By T. H. McHatton, *University of Georgia, Athens, Ga.*

The Horticultural Department of the University of Georgia established an Elberta peach orchard of 1,000 June-budded trees in the winter of 1932–33 on a uniform area of Cecil clay loam that had been in alfalfa for five years. One of the objects of the experiment was to study yields. Trees were set at the rate of 88 to the acre and the orchard divided into 10 plots with buffers between. The experiment was to run for 10 years. Yields were recorded in pounds under each tree at harvest and if a tree died or was removed for any reason the records were discarded and do not appear in the final results. The experiment began with 70 trees per plot and the final results, at the end of 10 years, were recorded on from 25 to 47 trees per plot.

Table I shows the variations in cultivating cover cropping and fertilizing the orchard.

TABLE I—Establishment of Ten Plots of Elberta Peach Trees for Experimental Studies

Plot	Cover Crop	Treatment of Plot	Units Nitrogen Mar 1	Units Nitrogen Sep 1
1	None	Cultivated	0	0
2	Planted Oct 1	Cover crop plowed under Mar 1	1	0
3	Planted Oct 1	Cover crop plowed under Apr 1	1	0
4	Planted Oct 1	Cover crop plowed under May 1	1	0
5	Planted Oct 1	Continuous cover	1	0
6	Planted Oct 1	Cover crop plowed under Apr 1	½	½
7	Planted Oct 1	Cover crop plowed under Apr 1	0	1
8	Planted Oct 1	Cover crop plowed under Apr 1	1	1
9	Planted Oct 1	Cover crop plowed under Apr 1	0	0
10	None	Cultivated	1	0

All plots received 16 per cent acid phosphate broadcast at the rate of 400 pounds per acre in September. All trees had the same amount of muriate of potash per year which was applied in the spring in increasing incuments with age, starting with ⅛ pound in 1934 and going to ¾ pound in 1938 and later. Nitrogen was the variable in fertilization; the unit in 1934 was ⅜ pound per tree and increased with age to 2¼ pounds in 1939 and thereafter. Pruning, spraying and general management were uniform. At the start there were 70 trees in each plot under identical conditions.

The average yield per plot and average yield per tree per plot for 7 years is shown in Table II. The seasons of 1937 and 1939 were frost years.

There is no significant difference between plots No. 2, 3 and 4 in which the variable was time of turning under cover crop. There is a significant difference between plot No. 5 (continuous cover) and all other plots. There is a significant difference between plot No. 3, which had all of its nitrogen in the spring, and plots Nos. 6, 7 and 8 which had all or some of their nitrogen in the fall. If plots Nos. 1, 9 and 10 are compared one with another and plots Nos. 2, 3 and 4 similarly

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[1] Published with permission of the Dean of Agriculture, University of Georgia as a portion of a forthcoming bulletin.

TABLE II—AVERAGE YIELD PER TREE PER PLOT IN POUNDS BY YEARS AND AVERAGE TOTAL YIELD PER TREE PER PLOT FOR SEVEN YEARS

Plot No.	1	2	3	4	5	6	7	8	9	10
Trees in Plot	25	34	34	35	29	34	36	47	30	28
1936	70.31	75.69	55.14	50.72	30.86	69.15	58.85	62.39	46.94	64.99
1937	25.94	24.74	21.71	30.84	9.85	21.91	22.76	35.46	32.54	16.94
1938	269.44	276.67	259.30	263.41	144.48	269.74	245.22	261.69	222.08	215.91
1939	90.16	187.26	141.74	195.40	129.69	210.29	202.69	200.87	153.07	106.14
1940	324.20	323.91	271.15	355.06	258.03	384.24	397.59	412.55	371.67	261.54
1941	230.84	310.76	301.56	341.46	255.14	363.12	305.05	310.91	258.73	224.29
1942	226.36	238.47	218.00	245.89	179.62	341.38	311.42	267.28	237.63	160.32
Total	1237.25	1437.50	1268.60	1482.78	1007.67	1659.83	1543.58	1551.15	1322.66	1050.13
Average per plot	176.75	202.36	181.37	211.83	143.95	237.12	220.51	221.59	188.95	150.02

33.4 pounds significant 5 per cent level.
42.9 pounds significant 1 per cent level.

TABLE III—PLOT NO. 7 YIELD IN POUNDS 36 TREES IN PLOT

Tree	R_1A	R_1B	R_2B	R_2C	R_3B	R_3C	R_3D	R_4A	R_4B	R_4D
1936	46.97	0.00	0.00	14.06	33.15	63.29	84.39	56.26	63.58	46.70
1937	57.00	31.50	21.75	22.00	65.00	55.50	23.00	18.00	2.50	37.00
1938	189.50	143.50	291.00	311.50	294.50	140.00	138.50	311.50	231.50	286.50
1939	347.00	236.00	309.00	467.00	338.00	351.00	231.00	242.00	189.00	189.00
1940	370.00	535.00	506.00	553.00	330.00	595.00	432.00	418.00	267.00	445.00
1941	446.00	172.00	406.00	633.00	441.00	359.00	349.00	252.00	396.00	342 00
1942	271.00	327.00	303.00	554.00	266.00	347.00	219.00	154.00	257.00	367.00
Total for 7 years	1727.47	1445.00	1836.75	2554.56	1767.65	1910.79	1476.89	1451.76	1406.58	1713.20
Average per tree	246.78	206.43	262.39	364.95	252.52	272.97	210.98	207.39	200.95	243.31

	R_5A	R_5D	R_7B	R_8B	R_8D	R_9A	$R_{10}A$	$R_{10}B$	$R_{10}C$	$R_{10}D$
1936	70.33	14.06	59.62	46.70	79.33	56.25	75.10	84.39	61.88	35.15
1937	24.50	17.27	31.75	9.50	3.75	5.00	9.25	20.00	60.25	13.50
1938	343.50	150.00	202.00	146.00	201.00	195.00	189.00	256.50	267.50	139.00
1939	228.00	237.00	306.00	155.00	233.00	81.00	177.00	206.00	159.00	43.00
1940	420.00	443.00	337.00	324.00	303.00	180.00	631.00	626.00	766.00	62.00
1941	332.00	237.00	525.00	130.00	348.00	231.00	400.00	261.00	268.00	218.00
1942	293.00	251.00	316.00	323.00	365.00	198.00	333.00	709.00	383.00	134.00
Total for 7 years	1711.33	1349.33	1777.37	1134.20	1533.08	946.25	1814.35	2162.89	1965.63	644.65
Average per tree	277.78	192.76	253.91	162.13	219.01	135.18	259.19	308.98	280.80	92.09

	$R_{12}A$	$R_{12}B$	$R_{13}A$	$R_{13}C$	$R_{14}A$	$R_{14}B$	$R_{14}D$	$R_{15}A$	$R_{15}D$	$R_{17}A$
1936	73.41	65.27	73.41	124.90	89.16	0.00	125.30	164.84	45.00	62.27
1937	5.00	30.50	40.50	38.25	32.50	16.00	2.00	32.25	37.50	12.50
1938	244.00	313.50	483.00	377.00	116.00	275.00	185.00	318.00	48.00	336.50
1939	218.00	139.00	295.00	247.00	145.00	131.00	124.00	145.00	322.00	94.00
1940	326.00	287.00	439.00	433.00	324.00	441.00	343.00	157.00	445.00	425.00
1941	431.00	190.00	441.00	315.00	266.00	126.00	79.00	19.00	226.00	168.00
1942	304.00	232.00	194.00	389.00	270.00	517.00	266.00	238.00	380.00	300.00
Total for 7 years	1601.41	1257.27	1965.91	1924.15	1242.66	1506.00	1024.30	1074.09	1503.50	1398.27
Average per tree	228.77	179.61	280.84	274.88	177.52	215.14	146.33	153.44	214.78	199.75

	$R_{17}B$	$R_{17}C$	$R_{17}D$	$R_{19}A$	$R_{19}B$	$R_{19}C$	Yearly Average Per Tree
1936	105.49	91.23	61.04	53.73	5.62	86.64	58.85
1937	20.75	22.25	1.50	0.00	0.00	0.00	22.76
1938	369.50	289.50	239.50	287.00	144.00	375.00	245.22
1939	223.00	37.00	240.00	91.00	25.00	97.00	202.96
1940	593.00	63.00	511.00	342.00	212.00	429.00	397.59
1941	509.00	162.00	845.00	353.00	260.00	346.00	305.05
1942	277.00	179.00	324.00	439.00	0.00	532.00	311.42
Total for 7 years	2097.74	843.98	1722.04	1565.73	646.62	1865.64	Average for 7 year period 1543.58
Average per tree	299.68	120.57	246.04	113.66	92.37	266.52	Plot average per tree 220.51

compared and a like grouping of plots Nos. 6, 7 and 8 is made, it is seen that the differences are not significant in these three comparisons. This indicates that soil uniformity exists throughout the planting, a point that should be noted.

On an acre basis of 88 trees for 7 years the average of yields (omitting fractions) run from 235 bushels for plot No. 5 (continuous cover) to 461 bushels for plot No. 6 or from 6¼ to 11½ tons, the latter figure being above the average tonnage per acre for California. At $20.00 per ton or 50 cents per bushel of 50 pounds, the lowest yield would have been profitable under Georgia conditions.

It is not these yields, however, that are of particular interest. A study of the production of individual trees is of more importance. Table III shows the behavior of the trees in plot No. 7.

There are similar tables in hand for each plot that show under all plot treatments as great a variation in individual yields as is to be seen in Table III for plot No. 7. When trees of the same variety, same age, under the same treatments, on a uniform soil and not over 22½ feet apart vary in yield as is seen from these records, the reason for this variation is a problem worthy of careful study.

In plot No. 7 the average tree yields varied from 92.09 pounds to 364.95 pounds or from 1.84 bushels to 7.28 bushels for 7 years. Trees R–17–A, R–17–B, R–17–C and R–17–D, all in the same row and closely adjacent varied from 120.57 pounds to 299.68 pounds or from 2.44 bushels to 5.99 bushels. Note also trees R–10–C and R–10–D adjacent trees, 22.5 feet apart, whose average 7 years yields vary from 92.09 pounds to 280.80 pounds or from 1.84 bushels to 5.61 bushels. Similar variations are found in the other nine tables not published.

Tree R–10–D, the lowest yielder in plot No. 7 had a 7 year average of 162 bushels on an acre basis of 88 trees while tree R–10–C, its immediate neighbor produced on an acre basis at the rate of 492.8 bushels for the same preiod. Tree R–2–C, the highest producing tree in plot 7, yielded an average acre rate of 642.4 bushels for the 7 years.

Discussion

Attention has been directed to soil uniformity as shown by grouping plots Nos. 1, 9 and 10; 2, 3 and 4, and 6, 7 and 8. The orchard site was carefully terraced; tillage and cover crops so handled as to reduce erosion to a minimum. All of the area selected had been in alfalfa for not less than 5 years and there were no badly eroded spots or small, incipient gulleys. The area occupied by each tree was $^1/_{88}$ of an acre or approximately 506 square feet, about as small an area as could be devoted to a single tree over a 10 year period. All efforts were made to eliminate soil variability.

As the variation between the trees within the plots, as seen in Table III, was greater than the variation between the plots, as seen in Table II, and as the differences between the plots was not significant in many instances, it is reasonable to assume a genetic difference between the trees. All of them were Elbertas, true to name and type, and may all be considered genetically the same. There can be only one genetic variable in the plants, namely the stock. All of the stocks were seedlings and as different in their behavior as any group of seedlings would be. High yielding trees must have congenial stocks adapted to the variety and the soil.

SUMMARY

The random distribution of low and high yielding Elberta peach trees under the same conditions of soil, climate and culture in this experiment leads to the conclusion that the great variable in all orchard peach trees is the stock and that asexual propagation of selected stocks adapted to varieties and soils is a problem of importance.

Factors Influencing the Keeping Quality of Dehydrated Apples[1]

By A. Lee Schrader, *University of Maryland, College Park, Md.*
and A. H. Thompson, *U. S. Department of Agriculture, Wenatchee, Wash.*

In 1942 investigations were started at the Maryland Agricultural Experiment Station on dehydration of apples, particularly to develop methods of producing a high quality of dehydrated product with the varieties grown in this Appalachian region and to study the factors that influence the length of storage life of the product, especially under higher than average storage temperatures. In early 1943 the first stored lots (York, Imperial, Stayman, Rome and Ben Davis), stored at 110 degrees F in hermetically sealed cans, quickly deteriorated in 8 days to a thoroughly blackened condition (Stage V, Fig. 1) and unpalatable flavor and odor which indicated the serious need for consideration of storage factors and dehydration methods that could modify such storage behavior, readily duplicated under temperatures of warm climate. Other experimental lots held at 33 degrees F and at room temperatures (mostly 60 to 70 degrees, with occasional summer rises to as high as 98 degrees F) showed little external change over a period of 12 months which is in accord with the experience of the industry in previous years. Ascorbic

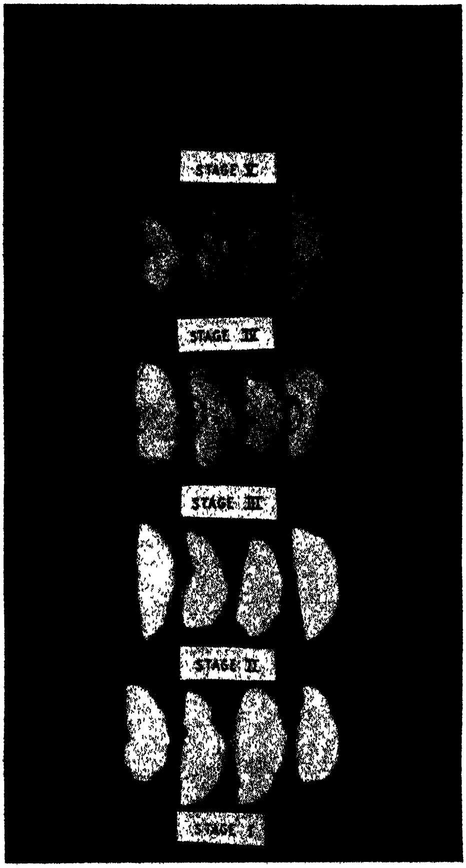

Fig. 1. Stages of darkening of dehydrated apples during storage. Stage 1 represents the material at beginning of storage.

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[1] Scientific Article No. A152. Contribution No. 2045 of the Maryland Agricultural Experiment Station (Department of Horticulture).

acid losses, however, were much greater at the higher temperatures than at 33 degrees F, showing that some changes had taken place.

Inasmuch as a positive peroxidase test with guiacol was found for the dehydrated apples before storage, the first storage tests had introduced a factor of enzymatic action. Therefore, in January 1944 a second series of storage lots, with material showing a negative peroxidase test as a result of a change in drying method, were subjected to three storage temperatures of 33 degrees F, 65 degrees F, and 100 degrees F and consideration was given to the effects of certain sulfuring and blanching treatments during processing and of packing atmospheres in the containers. A discussion of this later storage investigation will be given in this paper, although the detailed data on storage changes in terms of ascorbic acid, sulfurous acid and sugars will be presented in another publication of the Maryland Station.

METHODS OF PROCESSING, STORAGE AND ANALYSIS

Raw Material:—Stayman Winesap apples, 2½ to 2¾ inches in size, were hand-picked in October, 1943, stored at 33 degrees F until December when the fruit had ripened to a pressure test of 12 pounds and were firm-ripe for coring and peeling. Machine-peeled and cored fruits were dipped in .05 per cent sodium thiocarbamide solution, trimmed free of bruised spots or peel, cut by machine into 16 wedge-shape segments which were again dipped for 30 seconds in the thiocarbamide solution to prevent browning of the cut pieces during the period before sulfuring.

Sulfuring:—Six wooden trays with slatted bottoms, each tray holding 4 pounds of apple sections spread on the tray at 1.6 pounds per square foot, were placed in a nearly air-tight wooden sulfur chamber into which sulfur-dioxide gas was introduced. Since the SO_2 content of dehydrated apples has been considered important (4) in relation to the length of storage life, the following sulfuring treatments were made, including the use of a steam blanch, to increase the sulfurous acid content.

(a) Standard sulfuring for 30 minutes at the rate of 10 pounds per ton of fruit.
(b) Standard sulfuring as in (a) plus resulfuring after dehydration for 24 hours with 10 pounds of SO_2 per ton of fruit.
(c) Standard sulfuring as in (a) plus resulfuring after dehydration for 24 hours with 20 pounds of SO_2 per ton of fruit.
(d) Standard sulfuring as in (a) followed immediately by a 30-second steam blanch and later by resulfuring after dehydration for 24 hours with 20 pounds of SO_2 per ton of fruit.

Blanching:—The 30-second steam blanch, mentioned above, was accomplished after resulfuring by placing the six loaded trays under a steam box in which live steam was introduced and the temperature recorded with a thermocouple. A temperature of 210 degrees F was reached in about 20 seconds and the fruit was subjected to this temperature or slightly above for another period of 30 seconds.

Dehydration:—A two-stage tunnel of pilot plant size which held seven trucks with six trays on each truck was operated at a temperature of 210 degrees F in the primary stage of the tunnel and a temperature of 165 degrees F in the finishing stage. Trucks were held at the primary temperature for 105 minutes and at the finishing temperature for 135 minutes. Airflow in the tunnel was maintained at 1200 feet per minute with parallel flow in the primary stage and counter-flow in the finishing stage. These drying conditions resulted in a final moisture content in the conditioned product of 12.8 to 13.5 per cent except in the case of steam-blanched material which dried to 11.0 per cent. By use of steam-blanching and changing the time periods to 120 minutes in the primary stage and to 180 minutes in the finishing stage it was possible to dry apple segments to a moisture content of 5 per cent, far less than the usual 20 or more per cent of commercially dried apples. The importance of low moisture content in relation to storage life will be shown and such low moisture content as 5 per cent or less is not beyond commercial feasibility of production in tunnel machines as indicated.

Packing:—The browning and eventual blackening of dehydrated apples in the initial storage work of 1943 indicated the possible need of control of storage atmospheres. Accordingly, all lots were packed in No. 2 tin cans; some sealed in air; some sealed under vacuum of 28+ inches; and some sealed after air was replaced by carbon dioxide. To insure uniform moisture distribution, all dehydrated material was conditioned in covered wooden trays, 6 inches deep, for a period of several days before packing in cans.

Storage Conditions:—The canned lots of dehydrated apples from the sulfur and blanching treatments, as described, as well as one lot of material dried to 2.9 per cent moisture were placed at temperatures of 33 degrees, 65 degrees and 100 degrees F on January 20, 1944. A cork-insulated box, 5 feet square, placed in the 33 degree cold storage room was electrically heated to 65 degrees F to maintain this constant temperature. A similar box was used for 100 degrees storage, maintained within a degree. Apples packed in carbon dioxide and in vacuum were stored only under the high temperature of 100 degrees, since packing in air was sufficient for long keeping quality under the lower temperatures.

Analytical Procedures:—Samples during a 9-month period were taken at 90-day intervals from the material stored at 33 and 65 degrees F, and much more frequently from the lots stored at 100 degrees, as more rapid changes occurred at the high temperature. Observation of discoloration was made and recorded in terms of five stages shown in Fig. 1. Analyses were made for ascorbic acid by the titration method of Bessey and King (1), neutralizing the sulfur according to the method of Mapson (2). Sulfurous acid determinations were made according to the method of Nichols and Reed (5), as modified by Mrak (3) and further modified by Thompson by partially reconstituting the sample in cold water, followed by thorough maceration in a Waring blendor for 30 seconds and by distillation of more solution (about 250 milliliters) with each sample. Sugars and starch were determined by the Heinze and Murneek modification of the Shaffer-Somogyi method.

Samples taken of fresh apples before dehydration included segments from apples for each sample for analysis and samples of dehydrated apples included a minimum of 130 dried segments.

RESULTS

At 100 degrees F, the longest keeping quality, 9 months without visible change or discoloration and without apparent loss in edible quality, was recorded for the dehydrated apples that had been dried to a low moisture content of 2.9 per cent and contained a sulfurous acid content of 1466 ppm at the beginning of storage (lot 124 in Table I). It is probable that a longer storage life without change would have occurred if material from this lot had been packed in vacuum as there was evidence with the other lots that vacuum-pack had some influence. The other lots were decidedly poorer in length of storage life, although lot 123, dried to 11 per cent moisture, held up longer in vacuum or carbon dioxide pack than lots 120, 121, and 122, which can be ascribed to the slightly lower moisture content of the lot 123 and particularly to the higher sulfurous acid content (1768 ppm at start of storage). Steam blanching of lot 123 contributed to the higher sulfurous acid content, compared to 1321 ppm for lot 120, 1351 for lot 121, and 1407 for lot 122.

TABLE I—APPEARANCE OF DISCOLORATION IN DEHYDRATED STAYMAN WINESAP APPLES STORED AT 100 DEGREES F

Lot* Number	Nature of Pack	Days to First Discoloration (Stage II)	Days to Complete Discoloration (Stage IV)	Days to Inedible Condition (Stage V)
120	Air	36	60	90
120	Vacuum	60	90	120
120	CO_2	36	60	120
121	Air	60	90	120
121	Vacuum	60	90	120
121	CO_2	60	90	120
122	Air	60	90	120
122	Vacuum	60	90	120
122	CO_2	60	90	120
123	Air	60	90	120
123	Vacuum	150	200	270
123	CO_2	90	150	200
124	Air	270	—	—

*Treatments: 120—sulfured at 10 lbs/ton, dried; 121—sulfured at 10 lbs/ton, dried, resulfured at 10 lbs/ton; 122—sulfured at 10 lbs/ton, dried; resulfured at 20 lbs/ton; 123—sulfured at 10 lbs/ton, steam blanched 30 seconds, dried, resulfured at 20 lbs/ton; 124—sulfured at 10 lbs/ton, dried to low moisture at 2.9 per cent.

The effect of low moisture content of dehydrated apples in prolonging storage life at the high temperature of 100 degrees F was found to lie in the reduction of loss or change of sulfurous acid content during storage since in the low moisture material (lot 124) the sulfurous acid content was 759 ppm after 9 months compared to 400 or less in the other lots. Also the effect of vacuum and carbon dioxide pack was found to be in a diminished sulfurous acid change although not to a high degree with the higher moisture material.

Ascorbic acid losses served even more clearly to differentiate storage differences among the several lots and packing treatments, since the ascorbic loss was slightly less under vacuum pack than under CO_2

pack with all lots and the losses under air packs were distinctly more than either of the other two packs. The clear-cut superiority of the low moisture material (lot 124) in storage life also was reflected in the retention of one-third of the ascorbic acid after 270 days at 100 degrees F compared to complete loss of ascorbic acid in the other lots after 200 days or even 150 days with some lots.

The complete data on ascorbic acid and sulfurous acid changes will be published later, and will include also the relatively smaller losses that occurred in material at the lower storage temperatures of 33 and 65 degrees F, which showed no visible change during the course of the storage treatments.

It was evident that a low moisture content of dehydrated apples plus an initial relatively high sulfurous acid content was necessary to lengthen the storage life to practical limits under conditions of high temperature (100 degrees F). Some additional storage life could be expected by the use of vacuum pack.

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Atmospheric Changes Occurring in Film-Wrapped Packages of Vegetables and Fruits[1]

By L. E. Scott and Salah Tewfik, *University of Maryland, College Park, Md.*

Transparent films are being used extensively in the packaging of fresh vegetables and fruits in consumer sized units. Such packaging may involve placing the produce in a bag fabricated from the film, in overwrapping a cardboard tray or box containing the produce with the film sheet, or in wrapping individual units with the film. Since the packages are usually closed by sealing the overlapping edges of the film by application of heat or adhesive, the permeability of the film to gases will determine the extent of alteration of the enclosed atmosphere caused by the respiratory processes of the packaged produce.

This paper presents data on (a), the carbon dioxide accumulation and oxygen depletion in film enclosed packages and the effect of such changes on the enclosed products; and (b) the rate of carbon dioxide production by film enclosed produce.

Materials and Methods

The films used in the tests were obtained directly from the manufacturers[2] and are designated in the text by the code identification used in the trade. Packages were fabricated from sheets of film by sealing the edges together. All of the films were heat sealed with a "Sealtight" machine except Lumarith and Pl cellophane which were sealed with cellulose tape. All of the packages were tested for leaks by submersion in water before gas analyses were made, and any packages showing leaks were discarded.

Constant temperature cabinets controlled within 0.5 degrees centigrade or less were used for storing the products. Gas analyses were made at the end of the storage period by collecting the enclosed atmosphere over acidified water by displacement in a graduated cylinder and removal of a sample for carbon dioxide and oxygen analysis using a Fisher-Orsat absorption type apparatus. Measurements of carbon dioxide escape from the packages were made with a constant flow respiration assembly connected to chambers placed in the constant temperature cabinets. Essentially similar apparatus has been used and described by Kimbrough (2). Carbon dioxide production of the unpackaged products for purposes of comparison were also obtained.

Vegetables used in the experiments were grown on the University Plant Research Farm, were harvested at an optimum stage of quality, and were packaged within a few hours after harvest.

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[1] Scientific Paper No. A154, Contribution No. 2049 of the Maryland Agricultural Experiment Station (Department of Horticulture).

[2] The films used in the tests were supplied by the following firms: Celanese plastics Corporation, E. I. DuPont de Nemours and Company, The Goodyear Tire and Rubber Company, and Sylvania Corporation.

RESULTS — EXPERIMENT I

GAS ANALYSES OF THE ENCLOSED ATMOSPHERE

Tests With Tomatoes:—Rutgers tomatoes of firm ripe stage were packaged in seven types of cellophane and Lumarith. Each package contained about 500 grams of fruit and an enclosed atmosphere volume of from 500 to 600 milliliters. Gas analyses of the different lots after 4 days storage at 70 degrees F are given in column 1 of Table I. All of the cellophane packages except Pl showed carbon dioxide accumulations between 11.0 and 17.7 per cent and oxygen depletion to between 0.4 and 1.2 per cent in the enclosed atmosphere. The Pl cellophane and Lumarith packages were much lower in carbon dioxide and higher in oxygen content. The tomatoes packaged in all of the cellophanes except Pl were of decidedly off-flavor, with a fermented acid taste making them inedible. The Lumarith and Pl lots had no off-taste. It was also found that only the tomatoes in the Lumarith and Pl packages ripened during the storage period. The other lots showed little or no apparent ripening during the 4 days storage at 70 degrees F.

TABLE I—CARBON DIOXIDE AND OXYGEN CONTENT OF ATMOSPHERE IN FILM ENCLOSED PACKAGES OF FRESH VEGETABLES AND FRUITS

Type of Film Used in Package	Tomatoes Stored 4 Days at 72 Degrees*		Snap Beans Stored 7 Days at 38 Degrees		Sweet Corn Stored 5 Days at 38 Degrees		Lima Beans Stored 2 Days at 38 Degrees		Apples Stored 5 Days at 72 Degrees	
	Per Cent CO_2	Per Cent O_2	Per Cent CO_2	Per Cent O_2	Per Cent CO_2	Per Cent O_2	Per Cent CO_2	Per Cent O_2	Per Cent CO_2	Per Cent O_2
Cellophane										
300 Pl	5.5	12.8	4.8	10.3	—	—	—	—	—	—
300 PS	12.1	0.4	16.0	3.4	20.6	0.5	16.7	0.3	14.3	5.6
300 PDS	11.0	0.7	12.9	6.8	40.7	0.2	20.9	0.4	16.9	3.9
300 PMS	13.7	0.7	10.1	11.5	49.6	0.2	21.0	0.5	30.2	0.3
300 PMFS	16.5	0.7	27.3	2.2	27.0	0.1	21.9	0.4	29.6	0.5
300 PMB6CS	16.6	1.2	26.0	0.4	27.6	0.2	22.4	0.4	—	—
300 PMFB6CS	17.7	0.8	30.7	0.7	23.2	0.2	22.0	0.4	—	—
300 LST	18.9	0.4	—	—	—	—	24.7	0.5	27.4	2.4
300 MSAT	9.9	9.3	—	—	—	—	20.0	3.6	15.0	5.2
Lumarith	2.8	15.7	5.0	12.6	8.6	10.8	—	—	—	—
Pliofilm:										
75 P6	—	—	—	—	—	—	20.6	1.4	5.6	1.2
120 P6	—	—	—	—	46.2	0.2	26.9	0.2	18.4	0.9
75 FF	—	—	—	—	—	—	17.4	0.4	3.5	8.7
120 FF	—	—	—	—	—	—	18.5	1.7	6.7	5.2
140 P6a	—	—	—	—	—	—	—	—	17.5	1.0

*LST and MSAT lots of tomatoes were stored at 38 degrees.

In another test using the cellophane types LST and MSAT in storage of tomatoes for 4 days at 38 degrees F, it was found that the LST packages analyzed 18.9 per cent carbon dioxide and 0.4 per cent oxygen and the MSAT packages 9.9 per cent carbon dioxide and 9.3 per cent oxygen. Tomatoes in the LST packages were inedible due to off-flavors, while those in the MSAT packages were satisfactory at the end of the 4 day period.

Test With Snap Beans:—Rival snap beans were washed, snipped, cut into 1-inch lengths, and packaged in the same type films as used in the tomato experiments. Weight of the beans in each package was 150 grams and the enclosed atmosphere volume from 125 to 175 milliliters. Gas analyses of the packages after 7 days storage at 38 degrees F are given in column 2 of Table I. Three of the cellophane packaged lots, PMFS, PMB6CS, and PMFB6CS showed carbon dioxide accumulations of 25 per cent or more with oxygen depletion to as low as 0.7 per cent. The types PMS, PDS, and PS showed less carbon dioxide build-up, ranging from 10 to 16 per cent and correspondingly less oxygen depletion, from 11.5 to 3.4 per cent. As with tomatoes the Lumarith and Pl films showed the highest permeability with carbon dioxide accumulation of about 5 per cent and oxygen depletion to about 10 per cent.

No deleterious effects on the quality of the beans either raw or after cooking were noted in the packages having a high carbon dioxide and low oxygen content. It was found furthermore that the beans in such packages showed less discoloration or darkening of the cut surfaces than unpackaged beans or beans in more permeable packages. This subject will be discussed in detail in a later paper.

Tests With Sweet Corn:—Golden Cross sweet corn was husked, trimmed, washed, and packaged using three ears to each package. Gas analyses were made after 5 days storage at 38 degrees F (column 3, Table I). It will be noticed that the carbon dioxide accumulation and oxygen depletion was quite pronounced in all packages except Lumarith. The high carbon dioxide build-up in the PDS and PMS cellophane packages does not bear out the indicated higher permeability of these films found in the tomato and bean tests. In other tests with cellophane packaged sweet corn in 38 degrees F storage it was found that the oxygen content was reduced to below 1 per cent and carbon dioxide increased to above 20 per cent during the first 24 hours of storage.

A very definite alcoholic, fermented taste was observed in the corn in all of the packages having high carbon dioxide and low oxygen content. In packages of low permeability this off-flavor was first noticed after 2 or 3 days storage at 38 degrees F.

Tests With Lima Beans:—Henderson Bush lima beans were shelled in a viner and washed before packaging, using 300 grams of beans to a package with an enclosed gas volume of from 400 to 600 milliliters. Gas analyses after 2 days storage at 38 degrees F are given in column 4 Table I. The gas analyses were remarkably uniform regardless of the type of film, with the carbon dioxide content varying between 16.7 and 26.9 per cent and the oxygen content between 0.2 and 3.6 per cent. At the end of the 2-day storage period the lima beans had developed a slight sweetish off-odor and flavor. Such a condition had been noted in earlier work (4) on storage of sealed packages of lima beans.

Tests With Apples:—Column 5 of Table I gives the gas analyses of packages of Gallia Beauty apples after 5 days storage at 72 degrees F. The cellophanes tested showed carbon dioxide accumulations from 14 to 30 per cent and oxygen depletion to values ranging from 0.3 to 5.6 per cent. Greater differences in gas content between the several Pliofilm types were exhibited in this test than in the lima bean test, the only other instance in which Pliofilm packages were compared. The Pliofilm 75 P6, 75 FF, and 120 FF showed only moderate accumulations of carbon dioxide, from 3.5 to 6.7 per cent. However the oxygen depletion was relatively great with these films so that the combined oxygen-carbon dioxide content was much less than 21 per cent. The Pliofilms 120 P6 and 140 P6 showed carbon dioxide accumlations of about 18 per cent and oxygen depletion to 1 per cent in the enclosed atmosphere.

Results — Experiment II

Carbon Dioxide Production of Film Enclosed Produce

The effect of alteration of carbon dioxide or oxygen content of the atmosphere upon the respiration rate of plant organs in storage has been reported by several workers (1, 3, 5). Since the gas analyses of the film wrapped packages given in Experiment I showed very pronounced changes to have taken place in the carbon dioxide and oxygen content of the enclosed atmosphere during storage, it is of interest to determine the effect of such changes on the respiration rate of the packaged produce as measured by carbon dioxide production. Comparative carbon dioxide production rates of packaged and unpackaged tomatoes, snap beans, sweet corn, and apples were determined by measuring the escaping and accumulated carbon dioxide over a given storage period. The escaping carbon dioxide was determined as outlined under Methods. Accumulated carbon dioxide in the tomato and bean tests was measured by puncturing the sealed package during a momentary opening of the respiration chamber, and flushing out the accumulated gas through the absorption columns. The calculated carbon dioxide produced during the flushing period was subtracted. In the sweet corn and apple tests the accumulated carbon dioxide was determined by gas analyses of the enclosed atmosphere immediately after the storage period.

Table II shows that all of the films caused a lower total carbon dioxide production from tomatoes during the 135 hour storage period at 72 degrees F. Carbon dioxide production of packaged fruits ranged from 38 per cent in the PDS cellophane package to 78 per cent in the Lumarith package. It was found that the degree of reduction of carbon dioxide respiration was not necessarily related to the retention of carbon dioxide in the package. Thus, the PMB6CS film retained al-

TABLE II—CARBON DIOXIDE PRODUCTION FROM PACKAGED AND UNPACKAGED TOMATOES STORED AT 55 DEGREES F

Packaging Film	Mg CO_2/Kg/Hr for 45 Hour Periods			Mg CO_2 Retained in Package	Total CO_2 Production in 135 Hours (Mg)
	First Period	Second Period	Third Period		
Unpackaged ..	25.4	21.7	22.2	—	3118.5
Lumarith......	22.8	13.8	16.1	50.3	2421.8
300 PMB6CS...	20.2	11.4	11.0	200.4	2117.4
300 PS.........	17.0	8.1	7.6	18.3	1489.8
300 PMFB6CS	7.9	8.5	10.1	209.6	1489.8
300 PMS.......	8.4	8.0	8.1	178.3	1280.8
300 PMFS.....	8.3	8.6	8.6	56.5	1204.0
300 PDS.......	7.3	7.6	8.5	143.6	1196.6

most four times as much carbon dioxide as the PMFS film but caused a much lower reduction in total carbon dioxide production. It should be pointed out that with all of the films much more carbon dioxide escaped from the package than was retained in the package at the end of the storage period.

The results with snap beans given in Table III again show lower carbon dioxide production of the packaged produce but the per cent reduction is not as great as with the tomatoes. The three films used in the tests with sweet corn, Pliofilm 120 P6, and the cellophanes PMB6CS and PS, reduced carbon dioxide respiration almost equally to somewhat less than half that of the unpackaged corn. The data in Table IV also show a much lower retention of carbon dioxide by the PS film but a similar reduction in carbon dioxide production to the other two films. Carbon dioxide production of Gallia Beauty apples packaged in Pliofilm 120 P6 and PDS cellophane and stored for 5 days at 72 degrees F was about two-thirds that of unpackaged fruit (Table V).

TABLE III—CARBON DIOXIDE PRODUCTION FROM PACKAGED AND UNPACKAGED SNAP BEANS STORED AT 38 DEGREES F

Packaging Film	Mg CO_2/Kg/Hr for 24 Hour Periods				Mg CO_2 Retained in Package	Total CO_2 Production in 96 Hours (Mg)
	First Period	Second Period	Third Period	Fourth Period		
Unpackaged	36.4	36.4	25.0	33.3	——	3146.4
300 PMB6CS	27.0	13.5	18.8	20.9	931.5	2856.3
300 PMFS	14.8	12.1	17.2	22.8	931.5	2537.1
450 PMFB6CS	17.0	10.7	17.4	18.7	769.5	2300.7
300 PDS	10.9	11.0	12.4	17.1	1019.0	2252.6

TABLE IV—CARBON DIOXIDE PRODUCTION FROM PACKAGED AND UNPACKAGED SWEET CORN STORED AT 44 DEGREES F

Packaging Film	Mg CO_2/Kg/Hr for 24 Hour Periods					Mg CO_2 Retained in Package	Total CO_2 Production in 120 Hours (Mg)
	First Period	Second Period	Third Period	Fourth Period	Fifth Period		
Unpackaged	44.6	95.9	60.0	103.5	54.7	——	8608.8
Pliofilm:							
120 P6	16.9	21.0	19.4	23.4	14.0	1802.0	4074.8
Cellophane:							
300 PMB6CS	5.9	22.5	22.0	31.0	24.7	1463.7	4010.1
300 PS	11.2	43.9	30.0	44.9	24.5	314.5	4022.5

TABLE V—CARBON DIOXIDE PRODUCTION FROM PACKAGED AND UNPACKAGED APPLES STORED AT 72 DEGREES F

Packaging Film	Mg CO_2/Kg/Hr for 24 Hour Periods				Mg CO_2 Retained in Package	Total CO_2 Production in 120 Hours (Mg)
	First Period	Second Period	Third Period	Fourth and Fifth Periods		
Unpackaged	27.8	31.2	26.0	25.8	——	3278.4
Cellophane:						
300 PDS	10.6	17.6	16.4	12.4	663.3	2328.9
Pliofilm						
120 P6	9.9	18.9	13.6	14.0	515.2	2204.8

DISCUSSION

All of the films tested permitted the accumulation of an abnormally high carbon dioxide content and the depletion of the normal oxygen content in the atmosphere surrounding packaged vegetables and fruits. The extent of the alteration depended more upon the kind of produce packaged and on the length and temperature of the storage period than upon the type of film used. Thus, packaged sweet corn showed a higher carbon dioxide and lower oxygen content after 5 days storage at 38 degrees F than did apples after 6 days storage at 72 degrees F. In many instances the oxygen content was found to be below 1 per cent indicating that complete anaerobic conditions were approached. The effect of the low oxygen-high carbon dioxide atmosphere on the quality of the packaged produce varied with the kind of produce. Sweet corn and lima beans were impaired very quickly in flavor, apples and tomatoes were affected more slowly, while snap beans were apparently not damaged. It would be hazardous to recommend any of the films used in the tests as a sealed wrap for fresh fruits or vegetables since the point at which accumulated carbon dioxide and/or oxygen depletion causes injury is a variable dependent upon many factors. For example the use of Lumarith (which caused no deleterious effects with tomatoes, sweet corn, or lima beans), caused the development of a very pronounced alcoholic taste in packaged peaches, even though the carbon dioxide accumulation and oxygen depletion was only to the 10 per cent level.

It must be emphasized that the data presented are from packages which were completely sealed. In testing a number of film overwrapped cartons as they came off a commercial wrapping machine, it was found that almost every package showed some air leak when tested by submersion in water. These leaks were apt to occur as punctures at the corners of the cardboard container or in a faulty seal at the ends of the package. Such leaks, even though very small, have been found to prevent excessive carbon dioxide accumulation and oxygen depletion in the package. Perforation of the film wrapper with 24 holes 1/8 inch in diameter very effectively prevented deleterious atmospheric conditions from developing in packaged tomatoes.

Although defective seals or intentional perforation of the wrapping film will obviate carbon dioxide accumulation and oxygen deficiency in the individual package, the problem remains of adequate ventilation of the master carton in which the packages are placed for shipment. This factor would be of especial concern when large numbers of the master cartons are loaded in a solid block for truck or rail shipment, and should be considered in the problem of proper refrigeration under such conditions.

The wide differences in the response of the vegetables and fruits used in the tests illustrate again the fallacy in attempting generalizations as to the physiological nature of horticultural material. Success in the use of transparent film wraps, if attained, will necessitate careful experimental trials with each type, possibly each variety of vegetable or fruit.

The decreased respiratory activity, as measured by carbon dioxide production, exhibited by the film enclosed produce cannot be directly compared with the findings of Platenius (3) or Thornton (5), since these workers maintained a constant level of either oxygen or carbon dioxide in the storage atmosphere while measuring respiratory response. Similarly, it is not possible to attribute the decreased carbon dioxide production to either carbon dioxide accumulation or oxygen depletion, since these two factors were changing simultaneously during the storage perid. However, it is this type of change that will occur in atmosphere surrounding fresh vegetables or fruits in packages which interfere with free gaseous exchange, and the resulting effects on the metabolism of the produce are of obvious interest. It is conceivable that the decreased respiratory activity noted generally in the packaged produce might prolong the storage life, as has been found in certain instances with carbon dioxide storage of apples (1, 6). But even if optimum levels of carbon dioxide and oxygen for increased storage life in packaged fruits and vegetables were established, it would appear impossible, judging by the results of the present experiments, to maintain such levels by depending upon the permeability of the packaging film used.

SUMMARY

Data are presented on the carbon dioxide and oxygen levels found in the atmosphere of film enclosed packages of tomatoes, sweet corn, snap beans, lima beans, and apples.

High carbon dioxide and low oxygen concentrations in the packages were found to have deleterious effects on the packaged produce. The extent of alteration of the atmosphere depended upon kind of produce, temperature and length of storage period, as well as upon the type of film used.

The respiratory rate of packaged produce as measured by carbon dioxide production was always less than that of unpackaged material.

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The Peruvian Cooking Papaya, Carica Monoica, A Promising New Fruit and Vegetable for the United States Corn Belt

By Charles F. Swingle, *U. S. Department of Agriculture, Estacion Experimental Agricola, Tingo Maria, Peru*

In our work at Tingo Maria to establish a modern experiment station in the Upper Amazon basin of Peru, we are working in the midst of a little known and most interesting flora. Most of the plants which might offer economic possibilities are of little promise to the continental United States, for we are really in the tropics, with some 150 inches of rainfall, with no temperatures below 50 degrees F, and with no excessively hot or dry weather.

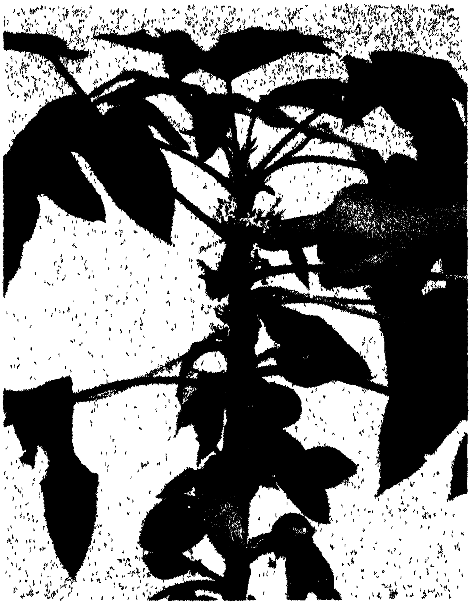

Fig. 1. Close-up showing male flowers at top with fruits below.

However, we have a Carica which we feel should be given wide trial in the United States. Though it is of the same genus as papaya, it can hardly be thought of in the same category, for it is inedible as a fresh fruit. However, when cooked with sugar and a little lemon or lime, it greatly resembles stewed peaches or apricots. Also, cooked leaves from mature plants, or entire young plantlets, make a very satisfactory leafy green vegetable. Under the climatic conditions prevailing at Tingo Maria, which except for excessive rainfall constitute good corn growing weather, this plant ripens fruit in 3 to 4 months from seed. Then it continues to bear for several months, but it definitely is a short-lived species. Hence, we feel that it can be grown as an annual throughout a considerable area of the United States and even into Canada. For trials in the temperate zone, we recommended starting as early as is safe from frost, planting in good fertile loam.

In its native home, this plant is called "Col de montaña" and "Pa-pay-é-ta," the one name indicating its use as a leafy vegetable, the other its relationship to papaya. It is frequently seen in a rather denuded condition, because its leaves are so highly prized as a vegetable. I have seen it near the highway over a distance of some 25 miles, and I understand it extends at least this far along another road. I have never seen it very far from a semicultivated condition. I have never heard of it being grown elsewhere in Peru.

Carica monoica was first described in 1802 by Desfontaines from greenhouse material grown in France from seed carried from Peru. This description was incomplete as it made no reference to its characteristic horny seeds.

There is no mistaking the plant, however, from this description, for it is indeed monoecious, each flower cluster consisting of a female flower surrounded by several male flowers. Since both this species and *Carica papaya* occur together, one would expect to find natural hybrids, if crossing was possible, but we have seen no evidence of this taking place, nor have we had any success in our attempts at hand cross-pollination.

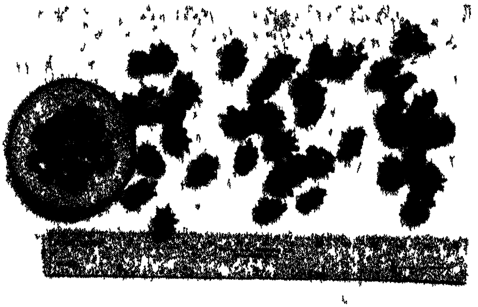

FIG 2 Cross section of ripe fruit and seeds showing characteristic "horns".

We have sent enough seed into the United States for extensive small scale tests. With the compliments of the Estacion Experimental Agricola of Tingo Maria we hope you will give it a trial and find out just where, if at all, this good South American plant fits into North American horticulture.

The 1946 Status of Chinese Chestnut Growing in the Eastern United States

By Clarence A. Reed, *U. S. Plant Industry Station, Beltsville, Md.*

The Chinese chestnut, *Castanea mollissima,* now dominates interest among well-informed chestnut planters of the eastern United States almost to the exclusion of other species. Since its introduction in 1906, it has had but one important competitor, the Japanese chestnut, *C. crenata.* Among the world's most important kinds of tree chestnuts, only these two species are effectively resistant to blight. However, the Japanese chestnut lacks the palatability to which Americans are accustomed, and for all practical purposes it has been rejected in this country. Many small plantings still survive; but this species serves better for shade and ornamentation than for food production.

DESCRIPTION OF THE CHINESE CHESTNUT

The nut of this species is usually of good size, roundish in form, not pointed at the apex, and with the basal scar smaller than the lower end of the nut. A certain amount of gray down is on the surface. This down may be confined to a small area about the apex or it may cover much of the upper end of the nut, and it may be thick, thin, or scant. The nut may have good cleaning quality, meaning that the kernel and its pellicle are easily separated. Cleaning quality may be good from the time the nut falls from the tree or it may become so only after curing for a time. Once it develops, it may remain good as long as the kernel is usable or it may last for a short while only. In texture and in palatability, the kernel of the Chinese chestnut is not excelled by any other true chestnut. Individual nuts are sometimes sweet from the first but the great majority become so only after being cured for a week or 10 days. Very few nuts of the pure species fail to be sweet when fully cured.

In the open the Chinese chestnut tree attains much the same size and general proportions as does the apple but it may become somewhat larger, more upright and considerably taller. Young seedlings vary greatly in form and are often ungainly and unsymmetrical; but others are all that could be desired with respect to symmetry. Early lack of symmetry tends to become less objectionable as the tree grows older and is seldom conspicuous after the first decade or so.

In fruitfulness, many of the seedling trees of bearing age are definitely disappointing. Also in many cases the nuts are small. To judge the species by the past fruiting performance of a majority of its representatives in this country would leave little justification for commercial hope. However, there are a good many individual trees about the country whose performance record is excellent and a large number of these are under careful observation as potential varieties.

The species has gained rapidly in popularity since the middle thirties when enough good-performing trees began bearing for a fair appraisal of the species to be possible. It was also at about that time trees for planting began to be available from nurseries. Before then trees could only be had in limited numbers from the Department of Agriculture. Today, they are listed in nursery catalogues of one or more firms in each of a half dozen or more states. The total number of trees yet planted is comparatively small and both nurserymen and planters up to this time have proceeded cautiously because of the newness of the industry and its uncertainties.

ENVIRONMENTAL REQUIREMENTS

The Chinese chestnut requires much the same conditions of climate, soil, and soil moisture as does the peach, but there are indications that it will succeed both somewhat farther north and south. As with the peach, air drainage must be good and frost pockets must be avoided, for while at the latitude of the District of Columbia, the flowering period is from late May until toward the end of June, growth begins early and may be badly damaged in April. This is especially true during such seasons as those of 1945 and 1946 in the middle Atlantic States when summer temperatures prevailed during a great part of March, new shoot growth up to 2 inches had developed when sub-freezing temperatures killed all new growth and so injured the buds that at Beltsville, Maryland, and general vicinity there were no crops in either year. In some cases young trees were killed outright as were occasional older trees that had become devitalized in some way.

Young trees are so sensitive to lack of soil moisture that sometimes whole plantings are killed by drought. Spring growth is rapid as long as the soil is moist, but root development is shallow during the first few years and, unless watered, trees are likely to fare badly in cases of prolonged drought. Another serious type of injury, especially to newly planted trees, is sunscald on the exposed sides of the trunks. Probably the best means of prevention is to head the trees low enough to provide for shading by the tops.

It is said (1) that at the altitude of 2,200 feet in West Virginia, snow and ice frequently cause much injury to young trees. It is a notable characteristic of the species for young trees to retain their leaves during much of the winter. Unless these are removed soon after turning brown, they are apt to become heavily weighted with wet snow and to cause severe breakage. Hail and spring freezes also cause much damage in that locality. The last, however, is not peculiar to high altitude alone as frost injury is frequent at much lower elevations. It was generally in evidence in central Maryland during the springs of 1945 and 1946, as has already been mentioned. This type of injury is easily overlooked, but the cambium will be found dark if a cut is made through the outer bark. Recovery usually takes place rapidly if the injured trees are left undisturbed, but healing will be slow if they are dug up for transplanting or the tops are severely cut back in preparation of the stock for grafting.

BEARING AGES

Young trees may bear a few nuts 3 or 4 years after being transplanted, but it usually takes from 10 to 12 years for tops to become large enough to produce profitable crops. While there are occasional trees that become profitable at these ages, there are many that do not. The only significant record of yields yet made public is one reported by Hemming (2). His statement shows that 18 seedling trees planted in 1930 bore an average of 29.5 pounds (green weight) during 6 of the 8 years from 1937 to 1944, inclusive, when crops were large enough to be separately recorded for each tree. The range in total production per tree for the 6 years was from 106 to 277 pounds. At an arbitrary price of 25 cents a pound, the average gross return per tree would have been $7.39 for each of the six crops. The 1944 crop was a practical failure. That of 1946, amounted to about 1,000 pounds or an average of about 55 pounds per tree.

THE SEEDLING TREE

The original planting stock of the Chinese chestnut as grown in the United States consisted wholly of seed nuts imported direct from the Orient. It was, therefore, inevitable that a period of seedling development should follow. The great majority of the earliest trees grown proved unfit for use as potential varieties, although with some exceptions, they produced nuts that were sweet and palatable. Since the middle thirties, superior strains have been introduced, cultural and environmental requirements have become better understood, and the outlook for commercial orchards is much improved.

To a great extent the seedling has served as well as would a grafted tree for the pioneer experimental work that had to be done. It has been far better than no tree at all and even now it has its advantages. With it there is no expense for grafting, no problems of congeniality between stock and scion and those of cross pollination are held at a minimum. Moreover, it must not be forgotten that it is only from seedling trees that superior varieties are possible. In 1946, very few grafted trees were available from any source.

THE GRAFTED TREE

The first varietal selections were made in 1930. Quite unavoidably they were chosen solely by what could be judged from the nuts with no knowledge of the bearing habits of the parent trees. These were first grafted in 1932 and first catalogued in 1935. Already by 1946, some have been supplanted by others of greater promise. Few grafted trees have been brought into bearing and with minor exceptions, it has not been possible to obtain bearing records. It is however, mainly with the grafted tree that the future of the industry is expected to be built up.

INDIVIDUAL VARIETIES

Abundance:—This variety was first catalogued in 1941 by Carroll D. Bush, then a nurseryman at Eagle Creek, Oregon. Of the very few trees of this variety sold by him, one went to Mr. Fayette Etter, Lemasters, Pennsylvania, with whom it early became a favorite among seven or eight he had under test. During 1945 he sent a quantity of Abundance chestnuts to Dr. J. Russell Smith, Swarthmore, Pennsylvania, who in turn forwarded 12 specimens to the Plant Industry Station. These arrived October 11 and were immediately placed in a refrigerator. On October 22, they averaged 50 to the pound and ranged from 38 to 76. The appearance was very attractive, as the color was a rich brown and there was very little down over the surface. The cleaning quality was also very good and the flavor excellent.

The Abundance has attracted considerable attention and, while it does not appear to be listed in any nursery catalogue, a number of leading growers are using it in top working seedling trees and it may soon be available through regular nursery channels.

Carr.—The Carr chestnut originated as one of two seedlings sent by the Department of Agriculture in 1915 to the late R. D. Carr, Magnolia, North Carolina. Sixty-two nuts from Mr. Carr were received by the Department in 1930. These were not especially attractive as the surface was thickly coated with gray down. The lot averaged 58 per pound and the nuts were considered large. Cleaning quality was very good and the flavor was sweet and pleasing. The variety was immediately named in honor of Mr. Carr, although propagation did not begin until 1932. It is believed to have been the first variety of the species ever grafted in this country. The work was performed by H. F. Stoke, Roanoke, Virginia. Later the Carr became available for several years from a number of nurseries. It was a strong grower but often failed to make good unions with its stock and is not now in general favor.

Hobson·—This also originated as one of two seedling trees sent to a private grower by the Department. This went to Mr. James Hobson, Jasper, Georgia, in whose honor it was named in 1930. It was later taken up by commercial nurserymen and widely distributed for several years. It has much in its favor as it is easy to graft, precocious, prolific, annual in bearing, and the nuts are very sweet. Also, the cleaning quality is very good, but the nuts are too small to meet market requirements of this country to best advantage. Furthermore, being small, they are expensive and time consuming of labor at time of harvest. The average per pound for a lot of 110 nuts received in 1930 was 78. Others received during later years were even smaller. The variety rapidly lost favor with most nurserymen and its propagation was largely, if not entirely discontinued. However, for home use, it is much too good to be abandoned at this time.

Reliable:—Reliable was an introduction of H. F. Stoke, Roanoke, Virginia, by whom it was propagated for a short time only, beginning in 1938. It is not known to have been catalogued by any other nurseryman. Ten fresh nuts in 1939 averaged at the rate of 79 to the pound. Six days later, after further curing had taken place, the number became 101 to the pound. Aside from having a good bearing record, there appears to be little reason for continuing this variety.

Stoke:—This variety appears to be the result of a natural Chinese x Japanese cross. The original tree was grown by H. F. Stoke, Roanoke, Virginia, whose attention was attracted to it because of its habit of maturing early. He reports that in southwestern Virginia, burs often begin opening during the third week of August. In appearance, the nuts greatly resemble pure Japanese. The parent tree bears well, but the nuts are lacking in good palatability. Insofar as known propagation has been discontinued.

Yankee (Syn. Connecticut Yankee)·—The Yankee originated as a chance seedling on property of E. E. Hunt, Riverside, Connecticut. It was first propagated by Dr. J. Russell Smith, Swarthmore, Pennsylvania, in northern Virginia by whom it was first catalogued in 1935 The writer has seen no specimens but according to Dr. Smith, the size and other features are very good. The parent tree is said to bear well and to be hardy where it is located, which is not far from Long Island Sound in the extreme southwestern corner of Connecticut.

Zimmerman:—This originated as a 1930 selection made by the late Dr. G. A. Zimmerman, Linglestown, Pennsylvania. Very few sound nuts of Zimmerman have ever been produced, for soon after the first crop the identity of the tree became lost and eventually it was destroyed, together with others in an overgrown nursery row where it stood. In one known case where there are grafted trees of bearing age, the nuts are regularly destroyed by weevils. Such nuts as have been seen by the writer have been of a dull brown color and have had surface down only about the apex.

The Zimmerman was first catalogued in 1938–39 by Dr. Smith. It is probable that as many trees of this variety have been sold and planted as of any one variety but performance records are difficult to obtain.

POTENTIAL VARIETIES

Other varietal selection are being made, mainly by the Bureau of Plant Industry, Soils, and Agricultural Engineering from trees at its various field stations. Some of these are already under test as grafted stock in various parts of the country. The most promising will be released to commercial nurserymen as soon as their superiority over existing varieties is established.

POLLINATION

There is much evidence that chestnut pollen is largely carried by insects, although this has not been fully established. The Chinese chestnut is largely, although apparently not wholly, self sterile; more than a single seedling or grafted variety should be included in any planting. Several seedlings or several varieties would be better. In seedling plantings, all trees that produce inferior nuts should be removed in order to avoid danger of undesirable pollen influence, either on nut characters, or on the genetic makeup of the embryos if the nuts are to be used as seed.

HARVESTING AND CURING

Chestnuts should be harvested daily as soon as some begin to ripen and drop to the ground. They should be placed at once on shelves or in curing containers with wooden or metal bottoms through which the larvae of any weevils with which the nuts may be infested cannot penetrate and reach the ground. In areas of infestation, these grubs soon begin to bore their way out of the nuts and leave conspicuous holes in the shells. All infested nuts should be promptly burned.

In order to cure chestnuts to best advantage, they should be spread thinly on floors, or on shelves, or in shallow containers as just described, and held in a well-ventilated room. They should be stirred frequently and held for from 5 to 10 days depending both upon the condition of the nuts and the atmospheric conditions at the time of harvest. During the period of curing, the nuts will shrink rapidly in weight and the color will change materially. Both luster and brightness will largely disappear and, although still attractive, the nuts will quickly become dull brown. Three weeks is about as long as Chinese chestnuts usually remain sound without special attention.

Chestnuts should be marketed as promptly as possible both to minimize deterioration and to take advantage of good prices which are usually highest early in the season.

STORING

Chestnuts in sound condition when stored may be kept fit for eating or planting for several months by any one of several methods. When available, cold storage with temperatures somewhat above freezing is the simplest and generally the most satisfactory method. Stratifying in a wire-mesh container buried deeply in moist but well-drained sand is very satisfactory and successful. Another method is to hold the nuts in a tightly closed tin container either in a refrigerator or in cold storage at 32 degrees F. Burying under a porch or in the shade of a house or even in a bin of grain, preferably wheat or rye, is also a good method. Regardless, however, of temperature or other conditions, germination is likely to begin in early March and nuts intended for planting should be hastened into the ground as promptly as possible after that time.

INSECT PESTS

The two chestnut weevils are the principal insects attacking the nuts. These are exceedingly well-known in certain large areas where the chestnut is grown and in these areas both are often extremely abundant. Unless checked in some way they often render whole crops unfit for use. One of the most effective means of control is to plant trees only in well populated poultry yards; however, in large developments, this is impracticable, and other methods must be employed. In preliminary work carried on by the Bureau of Entomology and Plant Quarantine at Beltsville, DDT has given very encouraging results in controlling the weevil. The weevils have sometimes been called curculios, under which name they were well discussed by Brooks and Cotton (3). The Japanese Beetle is also a serious pest as chestnut. Another insects pest which feeds on the leaves is the June bug or May beetle. It works mainly at night and feeds on the newest leaves. It is seldom seen and usually disappears about the time the operator becomes aware of its presence.

DISEASES

Blight is the disease attacking the chestnut tree with which the public is most familiar. The Chinese chestnut is strongly resistant, although not immune, as few old trees escape attack in areas where blight is prevalent. In most cases healthy vigorous trees of this species overcome the disease within a few years after being attacked. The ones that die are usually those that have been devitalized in some way. The nuts are subject to attack by any of several diseases either before or after the harvest. A preliminary report on these has been made by Gravatt and Fowler (5).

PRESENT EXTENT OF PLANTING

With few exceptions the known plantings consist of small numbers of trees about residences. Occasionally there are one or two hundred trees in orchard arrangement. Production is not large and in most cases all sound nuts are either consumed locally or used by nurserymen and others for planting. The quantity that has reached the wholesale market is known to be small, although a beginning in that field has been made.

FUTURE OUTLOOK

Extensive expansion did not appear possible at any time soon, until after the 1946 crop had been harvested. This was unexpectedly large and a number of tons are known either to have been planted immediately or set aside for planting in the spring of 1947. It is conceivable that annual production of nuts available for seed purposes will increase rapidly. In this case, the extent of planting within the next few years will be entirely a matter of speculation.

Extensive planting in the early future cannot be considered economically safe, for in addition to the usual number of problems that must be solved in establishing any new horticultural enterprise, chestnut growers must expect keen competition with imports from both Europe and Asia. At the outbreak of World War II an average of more than 16 million pounds of chestnuts were yearly being imported into this country (6). These imports will doubtless again appear with the return of normal international relations.

Furthermore almost an exact half-century ago, the chestnut outlook was regarded as being so bright that it could hardly go wrong. During the middle and late nineties extensive chestnut developments were established in certain eastern districts mainly by use of Paragon and other varieties of European parentage. Thousands of small plantings were developed about home grounds and occasionally there were large orchards. The greatest developments were conducted by top working suckers that sprung up from stumps of native chestnut trees on cutover mountain land. Hundreds of acres were handled in this manner. Without exception, all ended in financial disaster.

SUMMARY

The nut of the Chinese chestnut is an excellent product. It is unexcelled in sweetness and general palatability by any other known chestnut. The tree bears well and is about equally as hardy as the peach. It appears to require much the same conditions of cultural environment as does that species. It is practically the only species of chestnut now being planted by informed growers in the eastern part of the United States.

It is thus far grown in this country almost entirely as seedling trees. Variation is about what was to be expected, with the majority of bearing trees proving to be poor producers and, in most cases, with nuts too small to sell well.

Varietal selections of much promise are being made; the first appeared in 1930 and were first catalogued in 1935. Some of the earliest have already been dropped as their defects came to be known, and others of greater apparent promise have originated. The process of selection is constantly going on and further introductions should shortly appear.

By taking certain simple steps, chestnuts in sound condition may be kept in usable condition for many weeks.

The Chinese chestnut is subject to attack by certain serious natural enemies. These include both insects and diseases and the tree as well as the nuts are affected. However, all that are now known appear controllable.

Past planting has been largely limited to small numbers of trees mainly about residence grounds. The total number of trees available for planting has never been large, due chiefly to the scarcity of seed nuts needed for nursery use. Production, however, rose sharply with the harvest of the 1946 crop which was unexpectedly large. Annual production may continue to increase since the number of trees of bearing age is likely to become appreciably greater each year. Nursery planting is likely to be proportionately greatly. The extent of future planting will doubtless be correspondingly influenced.

Present enthusiasm over the Chinese chestnut is very great and it is possible extensive planting may soon take place. It is believed, however, that this would be unwise from an economic point of view. There are many uncertainties in connection with the industry in its present state of development, and, not improbably there will be keen competition in the market with imported chestnuts from both Europe and Asia as soon as international relations become normal.

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Longevity of Tung Seed as Affected by Storage Temperatures

By JOHN R. LARGE, DONALD L. FERNHOLZ, SAMUEL MERRILL, JR., and GEORGE F. POTTER, *U. S. Department of Agriculture, Bogalusa, La.*

SEED of tung, *Aleurites fordii* Hemsl., are short lived. For planting in the late winter or spring it is customary to use only seed of the crop of the previous season, although occasionally a seed will sprout after having lain in the ground a whole year. Merrill *et al.* (1) have reported experiments in which tung seed harvested in October were found to decline gradually in viability, beginning the following January. A rather rapid decline in viability of tung seed has also been reported by Shear and Crane (2).

A study was begun in 1940 at the United States Field Laboratory for Tung Investigations at Bogalusa, Louisiana, to determine how storage conditions would influence the period of viability. On November 7 of that year fruit was collected from seven individual trees in an orchard near Covington, Louisiana. The fruit of each tree was hulled separately and one-third of the seed stored in the loft of a garage, one-third in a basement, and one-third in a cold storage plant. The seed stored in the garage loft was subjected to the greatest variations in temperature. During the coldest nights of winter, temperature of the loft dropped practically to that outdoors, with minima in the range from 20 to 25 degrees F. In summer, owing to heat absorbed by the roof, the air temperature in the loft sometimes reached 110 to 120 degrees F. In the basement, the temperature remained rather constant throughout the year, ranging from 70 to 80 degrees F. The cold storage was maintained between 34 and 36 degrees F.

During the period December 24, 1940 to December 27, 1941, 16 plantings were made, each consisting of 105 seed, 35 from each storage lot. Merrill *et al.* (1) showed that the viability of seed from one tung tree may vary widely from that of another. Consequently the 35 seed representing each storage lot comprised 5 from each of the seven seed trees. Beginning January 27, 1942, monthly plantings of double size were made, with 70 seed from each storage lot, 10 from each tree. No germination occurred in seed from the loft or the basement in lots planted after October 27, 1941, and plantings from these two lots were discontinued after May 26, 1942. The monthly plantings from the cold storage lot were continued until February 28, 1943. The few seed remaining at that time were transferred to a domestic refrigerator in which a temperature of 38 to 40 degrees was maintained. Subsequently 70 seed were planted on April 20, 1944 and the remainder, 125 seed, on May 12, 1945. All seed were planted about 2 inches deep in sand in a bench of an *unheated* greenhouse. The seedlings were counted as they emerged from the sand, emergence being the criterion of germination for the purpose of this paper.

Empirical curves representing the trends in viability are shown in Fig. 1. Excellent germination, ranging from 80 to 89 per cent for the

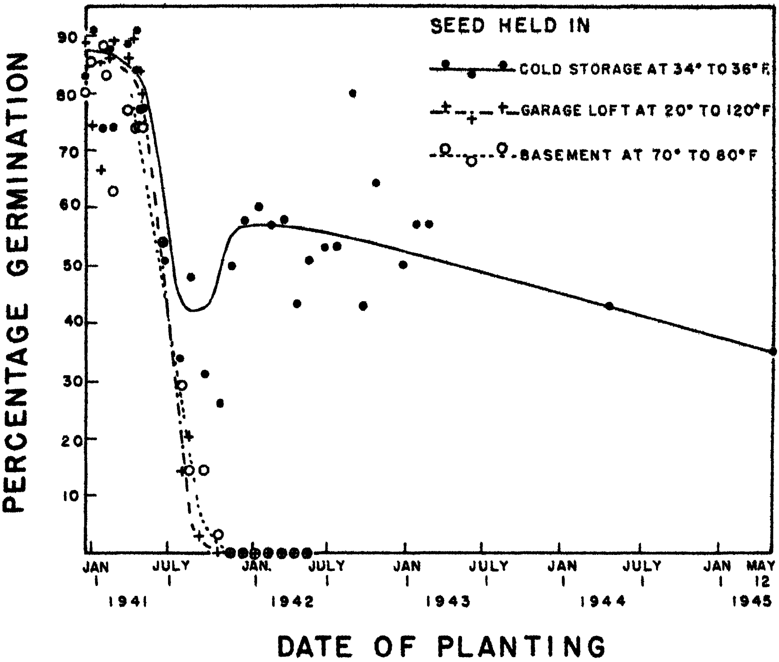

FIG 1. Emperical curves representing trends in viability of tung seed stored under different conditions. In November 1941 a better adjustment of the watering practice was made.

three lots, occurred in seed planted December 24, 1940, 47 days after harvest. This gives evidence that, although low temperature considerably delayed germination of seed planted during the fall and winter months, it did not reduce the final percentage of seedlings to emerge. The percentage of germination remained at a high level until June 26, 1941, after which it declined rapidly in the lots stored respectively in the loft and in the basement, until in plantings made in November 1941 or subsequently no germination occurred.

The germination of the cold storage lot also declined rapidly at first and fell to a very low point during August, September, and October 1941. However, it was found that the bed had been overwatered during these early months, a factor that may likewise have contributed to the lack of germination of many seeds from the lots stored in the loft and in the basement. In November and December 1941, when the moisture was properly adjusted, approximately 50 per cent germination took place in the seed from cold storage and none in the lots from the loft and the basement. Subsequently the germination of the cold storage seed declined gradually over a period of somewhat more than three years. In the last plantings, made in April 1944 and in May 1945, the percentages of seed to germinate were respectively 42.9 and 35.2.

On December 13, 1940 tung seed were also collected from six different trees in an orchard near Bogalusa, Louisiana, and divided into three lots, one of which was placed in each of the three storages previously described. These seed were planted 2 inches deep in the nursery at the Experimental Tung Farm on four dates during the season of 1941, namely, February 26, May 7, July 11, and September 4. At each date a total of 1,800 seeds were planted, 100 from each of the six seed trees in each of the three storage lots. The experiment was arranged in randomized block design with four replications. The data, presented graphically in Fig. 2, show that the seed stored in the loft and in the basement germinated well until July, after which the viability declined rapidly, with only 4.0 to 10.4 per cent germination for these two lots in the planting made September 4. At the first three planting dates germination of the seed of the cold storage lot was inferior to that of the lots from warm storage; but when planted September 4, a much higher percentage, 28.4, of the cold storage seed germinated.

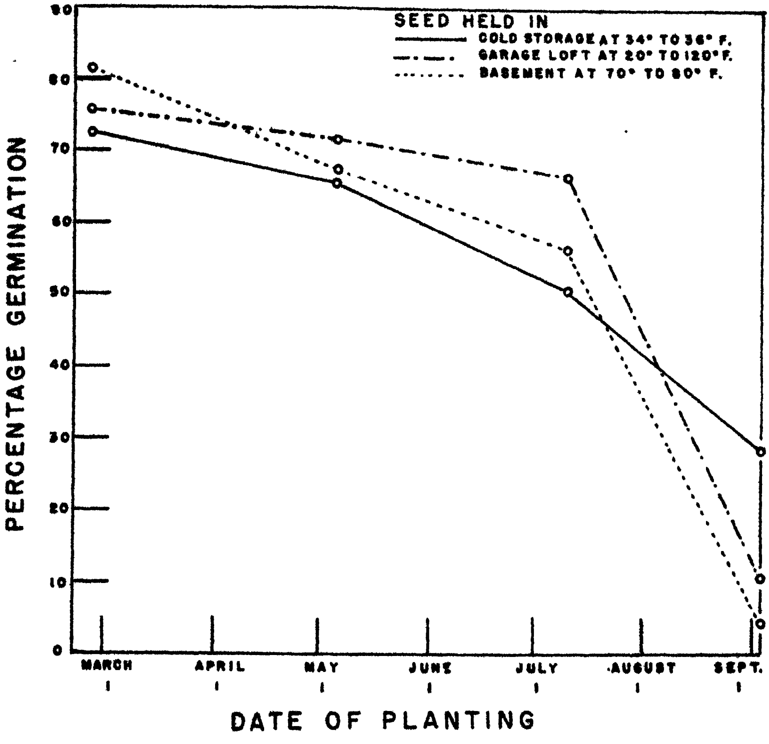

FIG. 2. Percentage germination of tung seeds placed in storage December 13, 1940 and planted in the field at four different dates in 1941. Each reading is the average of 600 seed, 100 from each of six individual trees — White Sand, Mississippi 1941.

Shear and Crane (2) have reported a somewhat similar experiment conducted over a period of 9 months, March to December 1941, at Beltsville, Maryland, using seed that had been stored in the garage loft at Bogalusa from harvest in November 1940 until March 1941. It was then divided into three lots, stored at 7 degrees C, at 23 to 32 degrees C, and 7 to 55 degrees C respectively. Their results were similar to those obtained in the nursery at Bogalusa, except that the seed stored in Maryland at room temperature (23 to 32 degrees C) and at 7 to 55 degrees C (in an attic) showed much better germination at the end of the storage period than corresponding lots stored in Bogalusa, and they also exceeded the germination of the Maryland cold storage lot. Simpson (3) has reported that viability of cotton seed declined most rapidly when held at high temperatures and in air that was high in humidity. Thus cotton seed failed to germinate after four years' storage under the climatic conditions of Baton Rouge, Louisiana, but showed 39 per cent germination after seven years' storage in the cooler and drier climate of Jackson, Tennessee. It seems reasonable to suppose that tung seed stored at ordinary temperatures in Bogalusa, Louisiana, would decline in viability more rapidly than seed stored at Beltsville, Maryland, because of the warmer and more humid climate of Louisiana. Because of the differences in the results obtained at these two locations, and in view of the recognized importance of the effect of moisture content on the longevity of seeds, further work on this factor seems to be indicated.

The individual readings of the short-term experiments in the nursery at Bogalusa and at Beltsville, Maryland, are more precise than those of the long term test. In the light of all the evidence the conclusion seems warranted that cold storage somewhat depresses germination of tung seed for about 9 months after harvest, in comparison with the seed kept at room or Southern outdoor temperatures. However, longevity of the seed is greatly prolonged by storage at 34 to 40 degrees F.

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Germination of Early-Planted and Late-Planted Tung Seeds as Affected by Stratification and Various Seed Treatments

By SAMUEL MERRILL, JR., *U. S. Department of Agriculture, Bogalusa, La.*

KNOWLEDGE of the factors affecting germination of tung seed is still rather incomplete judging from the reports on this subject appearing in the literature.

Shear and Crane (5) working under greenhouse conditions, found that (a) sphagnum moss, fresh sawdust, Berkeley Springs "F" grade sand, and medium glass sand were excellent substrates, but rotted sawdust was not, probably because of poor aeration; (b) for the substrates used, planting 1 inch deep gave best results; (c) the penetrant morpholine accelerated germination by 16 to 30 days.

Sharpe and Merrill (4) found that stratification of hulled seed outdoors in damp sand throughout the winter accelerated germination and improved the final stand.

Li (2), working in New Zealand, reported that seeds stratified in moist sphagnum moss at 32 and at 38 degrees F emerged more quickly and gave a somewhat better stand than seed stratified in the same medium at 40 to 60 degrees F.

Barton (1), citing work done at the Boyce Thompson Institute, stated that a 92 per cent germination of tung had been obtained at a constant temperature of 77 degrees F. However, at 68 degrees F only 8 per cent germinated, and at 86 degrees none at all. Pretreatment in a moist medium at 33.8 to 50 degrees F, followed by greenhouse temperatures of 68 to 86 degrees F, produced 58 per cent germination in comparison with 2 per cent for seed given no pretreatment.

Since considerable quantities of tung seed are planted annually in the southeastern United States by nurserymen and growers, experiments were initiated in the late winter of 1941 to obtain further information on the most important factors affecting germination.

MATERIALS AND METHODS

The following germination treatments were tried:

1. Seed were stratified (a) in warm damp sawdust, (b) in warm damp sand, and (c) in cool damp sand.
2. Seed were treated in 1 per cent aqueous morpholine penetrant for 48 hours just prior to planting.
3. Whole fruits were soaked in water for 24 to 48 hours, then broken into sections each containing one seed, and planted.
4. Miscellaneous treatments were used, consisting in (a) scarification on an emery wheel; (b) cracking the shell; (c) cracking the shell and placing seed in an atmosphere of oxygen prior to planting; (d) planting at extremely shallow depth; and (e) planting shallow and covering the seed beds with tar paper.

All methods were compared with planting dry, hulled seed 2 inches deep, which in this paper will be designated the check.

Sand used in the experiments was rather coarse in grade and was not thoroughly cleaned, except in 1941 when builders' sand was used. In the warm stratification an attempt was made to keep the seed at a temperature of 77 degrees F based on the findings reported by Barton (1). Seed were stratified either in a furnace room at 62 to 82 degrees F, or a solar frame at temperatures ranging from 48 to 76 degrees F.

Following treatment, the seed were planted in the nursery in accordance with conventional practice, except as noted hereafter. Counts of emergence, which was usually complete by June 20, were made at weekly intervals beginning about 30 days after planting. Plants emerging later than June 20, if any, were not included because they would not have had sufficient time before cold weather to attain satisfactory size.

In 1943 determinations of the moisture content of seed of each treatment were made at 10-day intervals from January 25 to April 15, thus including readings both before and after planting. This information was correlated with the time and rate of germination.

RESULTS

Effect of Parent Tree Strain:—Parentage had an important bearing on percentage emergence as was expected from results of previous studies (3, 4). Open-pollinated seed from the M–1 tree gave 88 per cent and that from M–49 gave 72 per cent emergence in 1942. In 1941 when the seed was probably unusually variable in viability, A–36 produced a stand of 72 per cent but M–46 only 21 per cent. Since the fact that seed of individual trees differ widely in viability is already supported by extensive data (*loc. cit.*), detailed results will not be presented for the different strains of seed used in this study.

Effect of Stratification:—Stratification outdoors for 75 to 100 days in cool, damp sand, accelerated emergence significantly and on the average increased ultimate emergence slightly over that of seed hulled and stored dry (Tables I and III). This corroborates the findings

TABLE I—PERCENTAGE EMERGENCE OF MORPHOLINE-TREATED, STRATIFIED, AND DRY-STORED TUNG SEED. AVERAGE OF TWENTY REPLICATIONS, FOUR EACH FROM FIVE PARENT TREES: L–99, M–1, M–39, M–49, AND M–51. (20 SEED PER PLOT, TOTAL 4,000 SEED). WHITE SAND, MISSISSIPPI, 1942

Seed Treatment	Planted February 17		Planted March 23	
	Early Count May 1 (Per Cent)	Final Count Jul 16 (Per Cent)	Early Count May 1 (Per Cent)	Final Count Jul 16 (Per Cent)
Treated with 1 per cent aqueous morpholine 48 hours just before planting	12.0	70.0	12.5	77.0
Stratified in warm damp sawdust last 41 days before planting	4.0	81.0	2.0	84.0
Stratified from Dec 12, 1941 to planting date in cool, damp sand	23.5	86.0	57.5	89.0
Stratified from Dec. 12, 1941 in cool, damp sand; transferred to warm, damp sawdust 41 days before planting	0.5	78.0	3.5	81.0
Check, seed hulled and stored dry	15.0	79.5	1.0	82.5
Least significant difference between readings:				
0.05 level	5.0	—	5.0	—
0.01 level	7.0	—	7.0	—

TABLE II—Percentage Emergence of Tung Seed Stratified Respectively in Warm Sand, Cool Sand, and Warm Hardwood Sawdust. Average of Four Replications of McKee Strain Seed from Tree Lanaux No. 769 (20 Seed per Plot, Total 480 Seed). White Sand, Mississippi, 1942

Seed Treatment Following Stratification From Dec 12, 1941 in Cool, Damp Sand	Planted February 25			Planted March 30		
	First Count May 8 (Per Cent)	Second Count May 16 (Per Cent)	Final Count Jul 16 (Per Cent)	First Count May 8 (Per Cent)	Second Count May 16 (Per Cent)	Final Count Jul 16 (Per Cent)
Transferred to warm, damp sand last 42 days before planting	29.0	62.5	81.0	5.0	45.0	80.0
Transferred to warm, damp sawdust last 42 days before planting	10.0	47.5	77.5	2.5	31.0	65.0
Not transferred	57.5	75.0	79.0	76.0	81.0	80.0
Least significant differences between readings:						
0.05 level	20.0	15.5	—	20.0	15.5	—
0.01 level	28.5	22.0	—	28.5	22.0	—

of Sharpe and Merrill (4). In 1943 seed transferred from cool to warm sand during the last 31 days of stratification, exceeded the cool stratified and dry stored seed in early emergence and gave a satisfactory final stand when planted in March, but gave generally inferior results when planted in February (Table III). In 1942, a similar stratification procedure retarded early emergence of seed planted either in February or in March (Table II). Transferring from cool sand to warm damp slightly weathered hardwood sawdust during the last 41 days of stratification retarded early emergence of both early and late planted seed in 1942, but gave a satisfactory final stand (Tables I and II).

Stratification in warm, damp sand only, 31 to 46 days before planting, consistently accelerated early emergence and in at least one case far more than cool stratification (Tables III and IV). In plantings made in April 1941 and March 1943, satisfactory final stands were obtained but the February 1943 planting gave a stand slightly inferior to the check. Nursery trees from seed stratified in warm damp sand only and planted in March 1943 slightly exceeded the check trees in height and diameter.

In 1942 stratification in warm, damp, slightly weathered hardwood sawdust only, gave a generally satisfactory ultimate stand of seedlings but retarded the rate of emergence. Exposure to harmful fumes of natural gas in the furnace room and lack of aeration in the sawdust as suggested by Shear and Crane (5) for their well-rotted sawdust substrate, may have contributed to inconsistent results with warm stratification.

Seed will sprout in a warm stratification bed, and, therefore should be planted before this occurs. It has been observed that if such seeds sprout before planting or are transferred to cold or dry soil just as they are about to germinate, emergence seems to be retarded and the final stand may be reduced. When transferred to the field under favorable environmental conditions, greater acceleration of emergence was obtained by warm stratification than by any other method tried in these experiments (cf. March planting, Table III). The hazards of using warm stratification can no doubt be minimized by (a) stratifying seed in warm sand for planting rather late in the season only, and when favorable conditions in the nursery may be anticipated; and (b) being very careful to move the stratified seed to the field at the best stage. The method would not be suitable for tung growing regions where spring droughts occur frequently.

TABLE III—PERCENTAGE EMERGENCE OF MORPHOLINE-TREATED, STRATIFIED, SOAKED, AND DRY-STORED TUNG SEED, AND GROWTH OF RESULTING SEEDLINGS. AVERAGE OF 5 REPLICATIONS FOR EACH OF FOUR PARENT TREES: L-96, M-1, M-22, AND M-49. (TEN SEED PER PLOT, TOTAL 2400 SEED). WHITE SAND, MISSISSIPPI, 1943

Seed Treatment	Planted February 20				Planted March 16			
	Early Count Apr 24 (Per Cent)	Final Count Jun 22 (Per Cent)	Final Height (Centimeters)	Final Diameter (Centimeters)	Early Count Apr 24 (Per Cent)	Final Count June 22 (Per Cent)	Final Height (Centimeters)	Final Diameter (Centimeters)
Treated with 1 per cent aqueous morpholine 48 hours just before planting . . .	55.0	76.5	123	1.86	15.5	83.0	125	1.90
Whole fruit soaked in water 48 hours; divided into sections containing one seed each.	20.5	71.5	114	1.79	1.0	64.5	115	1.77
Stratified from Nov 30, 1942 in cool, damp sand .	63.0	83.0	119	1.82	51.0	85.0	128	1.96
Stratified in warm, damp sand last 42 days* before planting	66.5	73.5	121	1.88	71.5	81.0	136	2.02
Stratified from Nov 30, 1942 in cool, damp sand; transferred to warm, damp sand 42 days* before planting .	49.5	55.5	135	2.08	84.0	85.0	126	1.88
Check, seed hulled and stored dry.	38.0	80.5	120	1.81	7.5	83.0	122	1.86
Least significant differences between readings:								
0.05 level.	4.8	4.6	11	0.15	4.8	4.6	11	0.15
0.01 level . . .	6.4	6.0	14	0.20	6.4	6.0	14	0.20

*31 days for seed planted March 16.

Effect of Planting Date:—In both 1942 and 1943 there were non-significant differences in final emergence between February and March plantings of hulled dry seeds. Generally, early planting is less likely to encounter spring drought. Stratified seed, which comes up quickly, may safely be planted later than dry seed.

Effect of Morpholine:—The morpholine treatments tended to hasten early emergence (Tables I and III), as reported by Shear and Crane (5), but the results were erratic and the ultimate stand showed small non-significant mean differences. Under the field conditions in southern Mississippi for the two years of the trials, the treatment was apparently less effective and less reliable than in the greenhouse experiments of Shear and Crane.

Effect of Miscellaneous Treatments:—Soaking whole fruits in water and breaking them into one-seed pieces for planting was inferior to the check in all respects (Tables III and IV). A ½ inch planting depth was inferior to 2 inches, no doubt because the surface soil was

TABLE IV—PERCENTAGE EMERGENCE TUNG SEED SUBJECTED TO EIGHT SEED TREATMENTS. AVERAGE OF FOUR REPLICATIONS FOR EACH OF SIX PARENT TREES: A-36, L-30, L-99, L-106, L-107, AND M-46. (20 SEED PER PLOT, TOTAL 3840 SEED). WHITE SAND, MISSISSIPPI, PLANTED MARCH 25, 1941

Seed Treatment	Count of May 16, 1941 (Per Cent)	Count of Jun 6, 1941 (Per Cent)	Final Count of Jun 20, 1941 (Per Cent)
Planted ½ inch deep	13.5	25.5	27.5
Planted ½ inch deep and covered with tar paper	29.0	42.5	43.5
Shell cracked	15.0	39.5	45.5
Shell cracked and seed placed 18 days in pure oxygen	14.5	42.0	48.5
Scarified on emery wheel	13.0	34.5	39.0
Stratified in warm, damp sand last 46 days before planting*	9.0	59.0	67.0
Whole fruit soaked in water 24 hours; divided into sections containing one seed each	7.5	35.0	48.0
Check, seed hulled and stored dry	17.0	50.5	58.5
Least significant difference between readings:			
0.05 level	7.5	8.5	8.5
0.01 level	10.0	11.5	11.0

*Stratified seed not planted until April 23.

too dry. Planting the seed ½ inch deep and covering for 6 to 7 weeks with black builders' tar paper resulted in a high rate of early emergence, probably because the soil temperature was raised, but later the soil became dry and the ultimate stand was inferior to that of the check. Cracking of the shells proved definitely harmful.

Relation of Moisture Absorption to Germination:—In 1943, moisture content of the kernels was obtained by sampling every 10 days both before and after planting from reserve lots of the seed of each treatment held in the actual place of treatment or subsequently in the seed bed. Moisture was determined by drying at 100 to 103 degrees C at atmospheric pressure. Data illustrating the trends in moisture content and also the date of first sprouting for four treatments are shown graphically in Fig. 1. Other data are presented in the text.

In general germination or sprouting was correlated with moisture absorption. It appears that prior to germination the maximum moisture absorbed by the kernels was equivalent to about 40 per cent of their dry weight; simultaneously with sprouting or just before sprouting was visible, more water was absorbed.

Seed that had been stratified in warm sand increased in moisture content, beginning at an early date and germination was initiated while the seeds were still in the solar frame. For example, seeds stratified in cool sand in late November and subsequently placed in warm sand in early January had a moisture content of 45.3 per cent by January and 60.6 per cent by February 3, when the first signs of germination were observed. Although seeds stratified in warm sand without the pretreatment in cool sand gained in moisture content somewhat more slowly, initial germination was first noted February 3. The morpholine-treated seed attained the same moisture content in 11 days as did the soaked seed planted in sections in 21 days, and the dry hulled seed in 31 days. Sprouting of the morpholine-treated seed was not correspondingly advanced, although it emerged significantly earlier than the dry check and the soaked seed (Table III). That factors

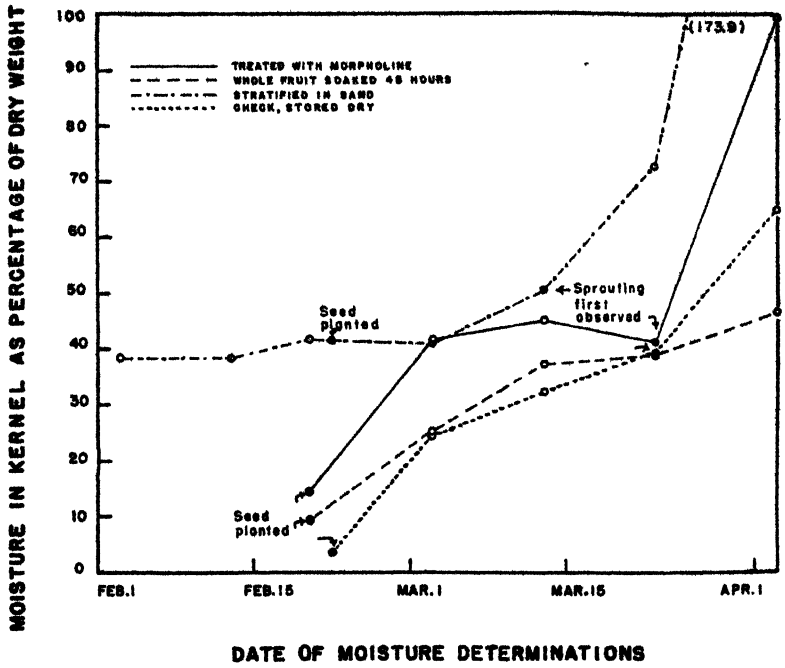

Fig. 1. Trends in moisture content expressed as percentage of the dry weight of kernels from tung seed planted at White Sand, Mississippi, February 20 to 22, 1943, (1) treated with 1 per cent aqueous morpholine for 48 hours just before planting, (2) soaked 48 hours in water as whole fruit and planted in sections containing one seed each, (3) stratified from November 30, 1942 in cool damp sand, and (4) hulled and stored dry until planting. Each reading represents average for 16 kernels, 4 from each of 4 parent trees: L–96, M–1, M–22, and M–49.

other than moisture absorption are concerned is further evidenced by the fact that on March 3 the seed stratified in cool sand and that treated with morpholine both had taken up a little over 40 per cent of water, yet the stratified seed began to sprout within 10 days, whereas the morpholine lot of seed required about 3 weeks to germinate. Enzymatic and other physiological changes of the seed had no doubt taken place under stratification and had prepared the seed for germination as soon as temperature and other conditions permitted. The time lag, after taking up about 40 per cent moisture and before germination of the morpholine-treated seed, may well have represented the time required to complete these physiological processes. The same general trends in moisture intake and subsequent development for morpholine-treated and other lots of seed were noted for the March plantings.

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Colchicine Polyploidy Technique with Peach and Pear Varieties

By HAIG DERMAN, *U. S. Plant Industry Station, Beltsville, Md.*

ABSTRACT

Two articles containing details on colchicine polyploidy of peach and of pear varieties, respectively, will be found in the *Journal of Heredity.*

RESULTS of greater value may be expected from polyploidy if it is induced in known varieties of tree fruits. Polyploidy experiments were carried on earlier with cranberries. Principles learned from the cranberry work were successfully applied to the polyploidy work with peach and pear varieties. Selected varieties were grown in the greenhouse and colchicine was applied in drops to the young shoot tips. A 1-per cent solution of colchicine in water with 2 drops of 10 per cent Santomerse to each 10 cubic centimeters of colchicine solution is recommended for peach treatment, and a 1-per cent solution of colchicine in 10 to 50 per cent glycerine in water, with Santomerse at the above proportion, is recommended for pear treatment. Growth from the treated tips or from the axillary buds in the treated portion should reach a considerable length before the presence of polyploidy in the new growth is likely to be detected. Polyploidy is usually induced sectorially and periclinally, but seldom totally in all the tissues. Inducing polyploidy in fruit trees seems quite easy; the difficulty lies in the isolation of it. The underlying factors in the isolation of polyploidy and the details in the technique of application of colchicine are to be found in the articles on cranberry *Amer. Jour. Bot.* 1944, 1945, 1947. *Jour. Heredity.* (in press.)

Leaf Gland Inheritance in Seedlings of Lovell and of Several Varietal Hybrid Peach Populations

By R. C. Moore and W. S. Flory, Jr., *Virginia Agricultural Experiment Station, Blacksburg, Va.*

Connors (1) and others have clearly described the type of inheritance encountered with the different kinds of leaf glands found on different varieties of peaches. Work in connection with the Virginia peach breeding programs has somewhat expanded these earlier findings, and while doing little more than confirming Connor's conclusions, does seem to merit a brief descriptive note.

Seed of "Carolina naturals" or "Tennessee naturals" have become increasingly scarce in recent years. Seed of the Lovell peach have been the most readily available to us, as a potential source for nursery stock, during the past few years. A number of peach propagations, of selections made in the Virginia breeding program, have been made on seedlings of this variety.

Leaf Gland Segregation in Lovell Seedlings

Since the Lovell peach has leaves with globose glands (3), which represent the heterozygous condition (1), its seedlings segregate with reference to type of leaf gland. During 1946 records were made on the leaf gland character of each of the Lovell seedlings in our nursery as an additional "marker" and possible check against mixture of the selections budded upon them.

Among the available seedlings of Lovell the following segregations with reference to leaf glands were observed: reniform—262; globose—541; and eglandular—272. It is obvious that this is extremely close to the ratio expected on the basis of a 1:2:1 ratio. The calculated chi-square value here is only 0.236 (which does not refute the hypothesis of a 1:2:1 ratio). The seed from which our material arose apparently resulted from practically complete self-pollination of the Lovell parents.

Both Connors (1) and Rolfs (4) have pointed out that a correlation exists between the eglandular leafed condition and susceptibility of plant to mildew, in peaches. We noted, even in the dry summer of 1946, that prevalence of mildew infection was apparent on each of the 272 eglandular seedlings, while seedlings with glanded leaves showed no mildew infection. Earlier a nectarine, P. I. 43142, with eglandular leaves, which had been selfed by us, had been noted to produce a progeny all of which had eglandular leaves only, and also all of which were quite susceptible to mildew infection. Dugger (2) has pointed out that a correlation also exists between the eglandular leafed condition in peaches, and susceptibility to peach leaf curl; we have made no observations on this point.

Where glands occurred on leaves records were taken of the average number per leaf for each seedlings. These records follow:

Number of Glands	Number of Seedlings	Number of Glands	Number of Seedlings
Globose		*Reniform*	
1	25	2	2
2	323	3	12
3	164	4	49
4	27	5	75
5	2	6	80
		7	24
		8	17
		9	1
		10	2

Two glands, or a single pair, represent both the mode and the median where globose ones occur. The arithmetic mean for seedlings with this gland type was 2.37, or just above a single pair. Where reniform glands occur, the seedlings with leaves having 6 glands represent the mode, the median falls at 5 glands and the arithmetic mean for gland number is 5.44. It is apparent that the range in gland number is greater and the mean considerably higher for leaves with reniform glands, compared with those having globose ones. Leaves on the same seedling, of course, with a few exceptions, have the same general type and number of glands, and our records were made on a seedling basis.

SEGREGATIONS IN PROGENIES WHERE HALEHAVEN WAS ONE PARENT

Fair-sized seedling populations were available from 13 hybrid peach combinations effected in 1944. Ten of these combinations were between parental varieties both of which had reniform leaf glands, and the entire progenies of all these also had reniform glands.

In the other three of the 1944 hybrid combinations Halehaven, with globose leaf glands, was used as a pollen parent; with other peaches having reniform foliar glands as the seed parents. These correspond, for the character considered, to backcrosses to the dominant parent. The leaf gland characteristics of these three crosses will be briefly discussed.

From the cross of selection R3–1 x Halehaven (reniform x globose), 146 seedlings were secured. Of these 72 had leaves with globose glands, 74 had leaves with reniform glands; a very close fit to the expected 1 : 1 ratio.

Selection R3–3 x Halehaven (reniform x globose) gave a progeny of 57 seedlings, 25 of which had globose and 32 of which possessed reniform glands on the leaves. This, too, is a satisfactory fit to a 1 : 1 ratio as is indicated by the chi-square value of 0.860 (which does not refute the hypothesis of a 1 : 1 ratio).

The cross J. H. Hale x Halehaven (reniform x globose) resulted in 119 vigorous seedlings in the hybrid test planting. Contrary to expectation, however, these were not equally divided with respect to the leaf gland character. Only one had leaves with globose glands, the other 118 had reniform glands. It seems improbable that any pollen mixture or confusion occurred, else the progenies mentioned in the two preceding crosses, resulting from pollen stored in the self-same vials, would be expected, likewise, to express some effect of this. This cross was repeated in 1946, and will be effected again; perhaps later progenies will throw more light on this point.

SUMMARY

Results of the leaf gland analysis of 1,075 seedlings derived from the Lovell peach, and of seedling populations of R3–1 x Halehaven, and of R3–3 x Halehaven, confirm that the reniform foliar gland character is a monofactorial dominant over the eglandular character, with the heterozygous condition being expressed in the form of globose glands. Progeny from a J. H. Hale x Halehaven cross, however, failed to segregate as expected — with reference to the gland character; no explanation for this is offered at present.

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Pollination Requirements of the Feijoa

By C. A. Schroeder, *University of California, Los Angeles, Cal.*

The assumption that partial self-sterility is exhibited by the feijoa *(Feijoa sellowiana)* has been held for many years with only meager experimental evidence for its support. It is the purpose of this report to present data which strongly confirm the above mentioned assumption.

Many of the feijoa plants grown in Southern California have been propagated from seed. When grown as hedges or planted in dooryard groups satisfactory bearing is generally the rule. Isolated seedlings or grafted plants of named varieties have been observed, however, which are poor yielders whereas others produce satisfactory crops. Plants of several varieties and of several hundred seedlings in the Subtropical Horticulture Area on the University campus regularly produce satisfactory crops, presumably because they have abundant opportunity for adequate cross-pollination.

Ryerson (1) in a preliminary investigation found that six different seedling plants were self-sterile. Clark (2) observed that bees were natural pollinators for the feijoa in California. Open pollinated flowers on some seedling plants set much better than covered flowers. He also states that hand pollination is practically 100 per cent effective. The percentage of self-fertility was determined in the following varieties: Superba (33 per cent), Choiceana (42 per cent) and Coolidge (100 per cent). Korolev (3) in Russia found that unpollinated flowers fell off and that cross-pollinated flowers set well and produced larger fruits. He also concluded that natural pollination was by bees.

The materials employed in the present investigation consisted of mature feijoa plants growing in the Subtropical Horticulture orchard on the Los Angeles campus. The varieties studied were Coolidge, Choiceana, Superba, Bliss, and Hirschvogel. Individual branches, each containing several flowers, were covered with cheese-cloth bags supported by wooden frames. All cross- and self-pollinated flowers were emasculated. Pollinations were made each morning. Open pollinated flowers were simply tagged and recorded. Covered flowers were protected by cheese-cloth, but were not emasculated. Observations on fruit-set were made about 3 weeks after the last pollinations had been done. The investigation was conducted during the two years 1945 and 1946.

The results of the self- and cross-pollination experiments given in Table I clearly indicate that in all the varieties studied except Coolidge there exists a tendency toward partial self-sterility. These data are supported further by observations of isolated Coolidge specimens which bear well, whereas isolated plants of the other varieties usually bear poorly. Choiceana and Hirschvogel are highly self-sterile while Superba and Bliss are partially self-fertile. The highly beneficial results from cross-pollination in increased fruit-set are evident in nearly all cases. There is no suggestion from the data that one variety is superior to another as a pollinator.

The observation made by others that the feijoa is primarily bee

TABLE I—RESULTS OF SELF AND CROSS POLLINATION EXPERIMENTS WITH FEIJOA

Variety (Pistillate Parent)	No. Flowers Pollinated	Per Cent Set
Coolidge (selfed)	101	87.0
Coolidge × Choiceana	29	86.0
Coolidge × Superba	33	87.8
Choiceana (selfed)	326	0.3
Choiceana × Superba	180	42.7
Superba (selfed)	365	43.8
Superba × Bliss	343	65.8
Superba × Choiceana	251	76.8
Bliss (selfed)	200	32.0
Bliss × Choiceana	85	67.0
Bliss × Hirschvogel	93	60.2
Hirschvogel (selfed)	95	5.3
Hirschvogel × Bliss	31	64.4

pollinated is further substantiated by the data in Table II. It is noted that open pollinated flowers which were extensively visited by bees set about 16 times as well as comparable flowers protected from insect visitations.

TABLE II—RESULTS OF SELF AND OPEN POLLINATION

Variety (Pistillate Parent)	No. Flowers Pollinated	Per Cent Set
Superba (open pollinated)	333	66.6
Superba (covered)	170	4.1
Choiceana (open pollinated)	325	17.8
Choiceana (covered)	62	0.0

These data warrant the conclusions (a) that the feijoa is pollinated by insects, primarily by bees; and (b) that most varieties show markedly improved fruit-set when cross-pollinated.

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Pollen Dilutents and Application of Pollen to Tree Fruits[1]

By F. L. Overley and R. M. Bullock, *Tree Fruit Branch Experiment Station, Wenatchee, Wash.*

Due to the heavy tree removal in recent years in the fruit districts of Washington, growers have become increasingly conscious of pollination problems. The condition has become acute in many orchards because of the reduction of the less important commercial varieties including Jonathan, Rome, Yellow Newtown, White Winter Pearmain, Winter Banana and other good pollenizing varieties. The new plantings are largely being made of the red strains of Delicious and Winesap. The Winesap is both self sterile and intersterile and the Delicious and the red strains of Delicious are self sterile but interfruitful with the Winesap. The result of this planting of Winesap and Delicious has caused many orchards to set light crops of fruit due to improper cross pollination. At the present time many large orchards are set in solid blocks of Delicious or Winesap without due consideration being given to pollenizing varieties.

Experiments have been conducted to improve the set of fruit by artificial pollination in addition to the work performed by insects. The following three methods have been tested, and have been used by fruit growers:

1. *Introduction of Bouquets in Trees:*—This method has proved satisfactory when the bouquets of known satisfactory pollenizing varieties are properly handled and insects are present.

2. *Grafting Pollenizers in Trees:*—This has proved to be one of the most satisfactory and economical of all methods when good pollinizers are used and are properly placed in the tree. Care must be taken in pruning and thinning and it may be necessary to import honey bees for pollination purposes. Hundreds of colonies of honey bees are imported into the orchards each season. Experiments conducted in 1946 indicate that Delicious and Jonathan are excellent pollenizers for Winesap, but Jonathan is not too satisfactory for the Delicious when bees are used as cross pollination agents, even though the pollen when applied artificially has given excellent set on the Delicious. The bees apparently prefer Delicious flowers to Jonathan flowers and they work on the Delicious blossoms before going to Jonathan. For good pollination this procedure should be reversed.

3. *Hand pollination:*—This method has proved to be very successful with careful operators but it is slow, laborious and expensive. The Tree Fruit Branch Experiment Station at Wenatchee has conducted many experiments in the collecting, curing, storing, diluting and actual use of the pollen. Pollen collected from flowers in the balloon stage and properly dried gives the highest per cent of germination. It requires 36 to 48 hours at 70 degrees F to allow the pollen to mature and

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[1] Published as Scientific Paper No. 696, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman, Washington.

dry properly. The viability of the pollen is reduced if it is over dried or dried too quickly, also pollen exposed to the sun will lose its viability very quickly. After pollen is properly cured it can be kept for several months under controlled temperature and relative humidity. The temperature for the storage of pollen should be approximately 34 degrees F and the relative humidity 25 per cent. Apple pollen has given satisfactory field results when it germinates above 35 per cent in a 10 per cent sugar solution.

METHODS OF APPLICATION

The first method used for artificial pollination of fruit was the hand method of application. Due to the slowness of this method and the labor involved, a number of different methods have been suggested and investigations conducted to determine their value. The following are some of the methods used with hand-collected pollen.

1. *Hand method:*—This method will give the most favorable results as indicated by the experiments conducted. The operator applies the pollen to each individual flower with a small stiff pig hair brush or with the rubber end of a lead pencil. A good operator can set approximately 100 per cent of the flowers touched with the right pollen, if weather conditions are favorable. Care must be taken that contact is made with gentle pressure of the brush or pencil containing pollen to all five stigmas of the pistil. Flowers opened only a few hours previous to operation are most receptive. Attention should be given to the shady side and tops of trees, since in most orchards native insects or bees work best in the warmest and protected portion of the tree. In orchards with a heavy bloom, one flower in every five clusters of bloom is sufficient for a heavy set and even then some thinning may be required.

Many growers consider hand pollination as an insurance and supplement it with bees and bouquets, however, many orchardists find the artificial pollination operation an added expense.

The following experiment was conducted in one orchard where natural methods of pollination were apparently adequate. Seven Delicious trees 20 years old were used in the experiment. The trees were selected for uniformity of size and amount of bloom. The same operator did the pollination in the recorded time allotted to each tree and later the same man did the thinning as uniformly as possible. The data in Table I show that there is a large variation in fruit set on the different trees, for example, Tree No. 6, with no pollination, set more fruit and required more time to thin than did Tree No. 2 and 5 where hand pollination was practiced.

Labor is the major item of expense connected with hand pollination of fruit. The cost of pollen at the 1946 prices would be about $8.00 per acre.

2. *Bellows Type Small Hand Duster:*—This method was used in experiments and by some growers to apply the pollen commercially. The experimental results indicate that it is not too good a method as it is very wasteful of pollen. It gave a high set of fruit on the portion

TABLE I—LABOR ITEM CONNECTED WITH HAND POLLINATION OF FRUIT TREES

Tree No.	Time Required to Hand Pollinate (Minutes)	Time Required to Thin Crop to a Uniform Set on All Trees (Minutes)	Total Time (Minutes)	Conditions of Crop Set
1	80	180	240	Very heavy
2	50	80	140	Heavy
3	60	110	170	Heavy
4	70	226	296	Very heavy
5	55	90	145	Heavy
6	None (Normal)	150	150	Heavy
7	None (Normal)	26	26	Light

of the branches dusted, but it was impossible to control the set. The results from this method required heavy thinning. The hand duster method however, was better adapted to the pollination on cherries than apples.

3. *Application of Pollen with Water Spray:*—A method of applying pollen with water spray was tried but not too successfully. The pollen in a water solution does not adhere to the stigmatic surface of the pistil. Pollen grains are apparently injured after 30 minutes in water.

4. *Airplane Method of Application:*—Many growers have used this method in the last 2 years. Experiments were conducted to compare the fruit set by airplane pollination with normal set. A portion of each of the trees was covered during the airplane flight, while the balance of the tree was open to both normal and airplane pollination. The pollen mixture used for airplane dusting was 25 per cent pollen and 75 per cent carrier (lycopodium).

TABLE II—FRUIT SET FOLLOWING AIRPLANE POLLINATION COMPARED TO NORMAL FRUIT SET ON DELICIOUS APPLES

Tree No.	Pollinated by Airplane			Normal Pollination			
	No Flowers Checked	Fruit Set	Fruit Set (Per Cent)	No Flowers Checked	Fruit Set	Fruit Set (Per Cent)	Increase Set by Plane
A	4,787	190	4.0	1,649	50	3.0	1.0
1	473	53	11.2	441	22	5.0	6.2
2	573	23	4.0	480	33	6.9	−2.9
3	568	54	9.5	557	28	5.0	4.5
4	601	47	7.8	601	45	7.5	0.3
5	573	41	7.2	468	30	6.4	1.2
6	546	51	9.3	622	35	5.6	3.7
7	568	24	4.2	596	27	4.5	−0.3
8	606	36	5.9	519	16	3.1	2.8
9	684	38	5.6	651	30	4.6	1.0
Total and average	9,979	557	5.6	6,584	316	4.8	Σ 17.5
						P = ±	0.684

The results show that pollination by airplane increased the set of fruit only 1 per cent. This is not enough to be significant, by the Student method of statistical analysis (1), since with 9 degrees of freedom "P" must equal 2.262 to be significant.

The results of this limited experiment with Winesap show an increased fruit set by airplane pollination, even with many honey bees

TABLE III—Fruit Set Following Airplane Pollination Compared to Normal Fruit Set on Winesap Apples

Tree No.	Pollinated by Airplane			Normal Pollination		
	No. Flowers Checked	Fruit Set	Fruit Set (Per Cent)	No. Flowers Checked	Fruit Set	Fruit Set (Per Cent)
1	5,353	523	9.8	1,550	135	8.7
2	3,256	291	8.9	3,310	156	4.7

present in the orchard. These experiments would indicate that the Winesap variety is more readily pollinated by pollen from air in dust form than Delicious. This is probably due to the structure of the flower. The pistils of the Delicious flower are short and often completely covered over with the many large anthers while in the Winesap flower the anthers are smaller. The pistils in the Winesap are more extended and exposed.

5. *Pollination by the Use of Bombs:*—Several thousand bombs for pollination purposes were sold and used by fruit growers during the 1946 season. The bomb was composed of a heavy cardboard cylinder with a fused impelling charge of powder in the base. The cylinder was filled with talc as a carrier for the pollen. The pollen was placed on the top of the talc, just prior to placing the bomb in the tree or on the ground to explode. The results of the experiments with apples are given in Table IV.

TABLE IV—Per Cent Set of Fruit from Bombs Compared to Normal Set of Fruit on Winesap

No.	Position on Tree	Pollination by Bomb			Normal Pollination			Increase Set by Bomb
		No. of Flowers	Fruit Set	Per Cent Set	No. of Flowers	Fruit Set	Per Cent Set	
1	S 18′	264	25	9.46	182	21	11.53	–2.07
2	NW 16′	110	11	10.00	132	15	11.36	–1.36
3	NE 18′	215	18	8.37	99	13	13.13	–4.76
4	S 8′	154	16	10.38	116	9	7.75	2.63
5	W 8′	176	19	10.79	171	15	8.77	2.02
6	N 8′	187	10	5.34	171	19	11.11	–5.77
7	W 16′	110	11	10.00	154	25	16.23	–6.23
8	S 8′	303	35	11.55	121	18	14.87	–3.32
9	W 8′	143	11	7.69	105	19	18.09	–10.40
10	S 14′	253	34	13.43	88	11	12.50	0.93
11	W 14′	242	23	9.50	193	19	9.84	–0.34
		2,231	213	9.87	1,532	184	12.01	Σ = 28.67
							P = ±	1.82

This decrease in fruit set by bomb pollination is not a significant decrease by Students Method of Statistical Analysis (1) since with 10 degrees of freedom "P" must equal ± 2.228 to be significant. The limited data obtained with this experiment would indicate the set of fruit was decreased when this method of pollination was used. Talc in other experiments has not proved satisfactory as a pollen carrier. It has a tendency to cover the stigmatic surface of the pistil the same as dust and apparently interferes with pollen germination. Lycopodium, the best of the pollen carriers studied being an explosive organic material, ignites when the bomb explodes, the pollen is injured and its viability is reduced.

USE OF GROWTH CHEMICALS WITH POLLEN

Experiments conducted with growth chemicals in pollination show a decrease in fruit set in this particular experiment. A thorough mixture with talc at 10 parts per million was used with the following: (a) Naphthalene acetic acid; (b) indolebutyric acid; (c) indoleacetic acid, and (e) talc alone. Pollen material was added to each at the rate of 10 per cent by volume. Talc mixtures were sufficient to coat the individual pollen grains thoroughly. The results of germination and fruit set are given in Table V.

TABLE V—FRUIT SET AND POLLEN GERMINATION WHEN GROWTH CHEMICALS ARE MIXED WITH THE POLLEN AT 10 PARTS PER MILLION

Variety Pollinated	Pollen Used	Pollen Treatment	Per Cent Pollen Germination	No. Flowers Pollinated	No. Fruit Set	Per Cent Fruit Set
Winesap	Jonathan	None	68	171	65	38.0
Winesap	Jonathan (e)	Talc	63	147	34	23.1
Winesap	Jonathan (a)	Naphthalene acetic acid and talc	57	142	32	22.5
Winesap	Jonathan (b)	Indolebutyric acid and talc	48	134	32	23.9
Winesap	Jonathan (c)	Indoleacetic acid and talc	10	150	36	24.0
Winesap	Normal set	———	—	305	137	44.9
Delicious	Jonathan	None	68	164	21	12.8
Delicious	Jonathan	(e)	63	158	10	6.3
Delicious	Jonathan	(a)	57	149	23	15.4
Delicious	Jonathan	(b)	48	114	8	5.7
Delicious	Normal set	(c)	10	175	20	11.4

The results indicate that proper mixtures were not used or the materials reduced the set of fruit over pure pollen. This reduction in fruit set is in agreement with the experiments with bombs where talc was used as a carrier for pollen.

POLLEN DILUTENTS AND TREATMENTS

An experiment was conducted in an effort to reduce the foreign material collected and dried with the pollen to a dust form for use in some of the suggested dusters for applying the pollen. The dried foreign material in the pollen is mostly anthers and pistils. The material tested was apple pollen. It was dried and ground to different stages of fineness in a mortar. The per cent germination was reduced in proportion to the treatment given. The germination of untreated pollen was 80 per cent; with slight grinding 30 per cent; moderate grinding 11 per cent; and severe grinding all material to a fine dust 5 per cent.

Experiments have been conducted since 1940 with different materials to serve as a dilutent for hand collected pollen. A good dilutent was desired to make artificial pollination more economical with dusting equipment, and for airplane application. Some of the different materials used in the experiments were, diatomoceous earth, different grades of bentonite, magnesium oxide, wheat flour, cake flour, lycopodium, walnut shell meal, corn meal, charcoal, different grades of ground douglas fir bark, dicolite, Fullers earth, and corn starch. Fruit set in experiments where the flowers were pollinated with pure pollen and with pollen containing some of the dilutents mixed 75 per cent by volume is given in Table VI.

TABLE VI—FRUIT SET WITH POLLEN DILUTED 75 PER CENT BY VOLUME COMPARED TO PURE POLLEN

Variety	Pure Pollen			Diluted Pollen			
	No. Flowers Pollinated	Fruit Set	Per Cent Set	Dilutent Used	No. Flowers Pollinated	No. Fruit Set	Per Cent Fruit Set
Delicious No. 1 ..	363	60	16.5	6	253	21	8.3
Delicious No. 2...	107	41	38.3	7*	137	1	0.7
Rome.....	112	56	50.0	14	108	0	0.0
Rome	112	56	50.0	1	88	1	1.1
Rome... .	112	56	50.0	3**	77	5	6.5
Rome.....	112	56	50.0	2**	125	17	13.6

*Mixture stood 12 hours before using.
**50 per cent dilutent added.
Diluent 14 is talc.

VARIATION IN SOURCES OF POLLEN AND COMPARISON OF FRUIT SET ON DELICIOUS AND WINESAP

Jonathan pollen was collected from different orchards. Germination tests were made and pollen was applied to emasculated flowers of Delicious and Winesap apples to compare the pollinizing value of pollen from different sources. The results are given in Table VII.

TABLE VII—GERMINATION OF JONATHAN APPLE POLLEN COLLECTED FROM DIFFERENT ORCHARDS AND SET OF FRUIT ON DELICIOUS AND WINESAP

Variety Pollinated	Pollen	Germination (Per Cent)	Fruit Set (Per Cent)
Delicious..	Jonathan No. 1	68	14.0
	Jonathan No. 2	46	10.2
	Jonathan No. 3	56	36.5
	Jonathan No. 4	53	33.3
	Jonathan No. 5	68	14.0
	Jonathan No. 6	46	9.4
Winesap.....	Jonathan No. 1	68	30.0
	Jonathan No. 5	68	38.2
	Jonathan No. 6	46	28.4

The results show the germination of pollen from different orchards vary from 46 per cent to 68 per cent. The fruit set on Delicious varied from 9.4 per cent to 33.3 per cent. The variation in fruit set was greater than the variation in germination. Comparative tests show that a higher per cent was obtained with Winesap than with Delicious with the same pollen.

SUMMARY

The most dependable results from artificial pollination from the different methods tested was with hand pollination. Airplane pollination gave promise for Winesap with the limited data obtained, but is of doubtful value with Delicious. Bombs, when talc was used as a carrier for pollen, gave less set than the checks. Of the 13 dilutents tested, lycopodium was the most satisfactory, but it can not be used in bombs because of its explosive character. Experiments conducted with pollen from different sources show some variation in set of fruit. The highest per cent set of fruit was obtained on Winesap compared to Delicious.

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Some Problems Involved in Securing the Prompt Evaluation of the Progeny of Apple Crosses

By M. A. Blake, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

In some apple producing districts, one of the most urgent problems is better varieties. The old practice of depending on the discovery of a worthwhile new variety as a chance seedling in some hedgerow or as a sprout from below a graft as a basis for the improvement of our commercial lists is no longer adequate for our modern industry. Too often in the past a worthwhile variety has been found in a northern apple district and recommended for trial and even planting in all apple districts. At great expense and loss, growers in the more southerly districts have too often found the variety unsuited to their climatic conditions. The climatic requirements of a new variety are not very difficult to evaluate, and these should be determined and announced at the time of introduction.

If the various apple districts are to obtain suitable modern varieties within a reasonable period of time, they will have to be produced by breeding. It requires a period of not less than 10 years to make a cross of two varieties of apples and evaluate the progeny as accurately as they should be before any one is selected and recommended for commercial planting. It then requires another 10 years before the variety can be brought into volume production. Even short delays of a few months in the various operations of breeding added to an occasional full season's delay can greatly extend the time when a breeder can offer his new product to the industry.

Any large-scale apple breeding work by state or federal service agencies will supposedly have as the main objective the development of varieties of greater economic value. This means that the length of time required to produce a new variety should be reduced as much as possible. This problem can best be discussed according to some of the various features of breeding, as for example:

1. The selection of parents.
2. The actual crossing or the hybridization of varieties.
3. The propagation of the progeny.
4. The culture of the progeny in the orchard.
5. The selection of the progeny.

A large number of crosses of apples can be made and great numbers of progeny secured within a few years time through the efforts of just a few persons. The number of trees that can be efficiently propagated, planted, fruited, and selected for superior commercial merit is a much more complex and expensive matter.

The seeds from apple crosses are often planted out-of-doors and if the seedlings attain a height of from 12 to 18 inches the first summer, breeders are often satisfied. It is in such cultural phases that the time element should receive attention. Experience at the New Jersey Station has shown that the rate of development of apple trees from seed can be advanced at least one year by the proper use of greenhouse

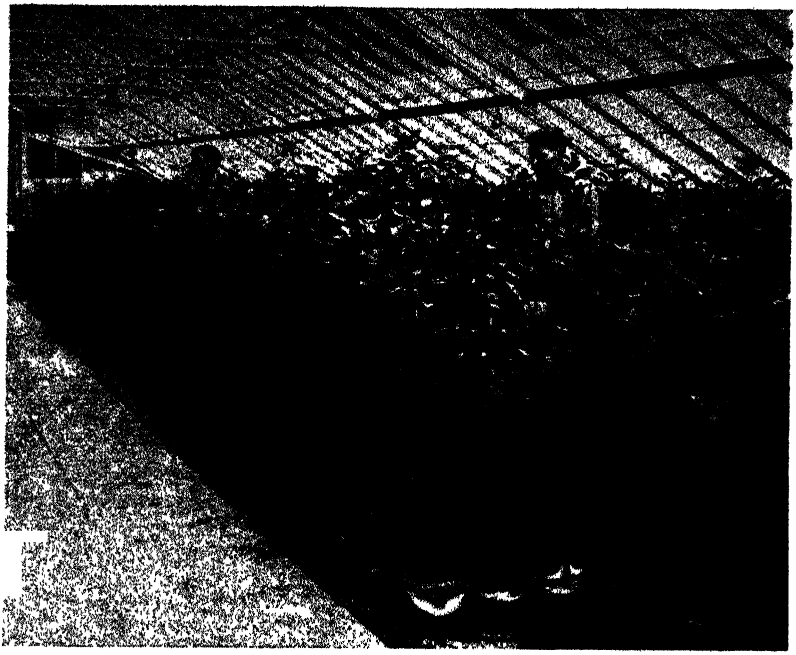

FIG. 1. The first summer's growth of apple trees grown from seed in a greenhouse.

facilities. Seedling trees from 3 to above 4 feet in height were secured in one season of growth by the use of pots in a greenhouse, as illustrated in Fig. 1.

ORCHARD CONDITIONS DETERMINE RATE AND CHARACTER OF TREE DEVELOPMENT

The rate of development of young apple seedlings in the orchard will depend on the environment, climate, soil type, nutrition, and culture. From the cultural standpoint, distance of planting is very important. If trees are to be brought into bearing as quickly as possible and in a condition of growth capable of efficient evaluation, they must have adequate light and moisture.

Under the growing conditions that prevail at New Brunswick, the minimum planting distance should be 20 by 10 feet or approximately 200 trees per acre. Even at a distance of 10 feet in the row, vigorous standard size trees may over-shade and crowd adjacent semi-standard or dwarf trees within a period of 4 or 5 years so that the smaller trees do not receive a fair test. Certain individual standard size trees planted 20 by 10 feet at New Brunswick have sometimes produced a few fruits for a season or two when from 5 to 6 years of age but became unfruitful when the planting was 7 to 8 years old because of overcrowding by adjacent, more vegetative trees. Thus, too close planting of trees may delay or even prevent efficient evaluation of commercial merit unless the trees are propagated and tested elsewhere.

GIVE THE TREES IDEAL CULTURE

The more rapidly the trees grow in a favorable environment, the sooner they will come into bearing. The first few years after planting in the orchard such insect pests as aphis, leaf hoppers, red mite, and tent caterpillars can inhibit the growth of the trees to such an extent that they will be delayed a full season or even several seasons before coming into bearing. Such diseases as apple scab can inhibit the tree development just as much.

In regions where the soil is too acid or deficient in one or more nutrients, special attention needs to be given to soil management; otherwise the unsatisfactory growth of the tree or fruit may be attributed to heredity or receive an incorrect rating.

A fruit grower is interested in knowing whether or not a variety is sensitive or susceptible to unfavorable factors of environment and injurious pests but he is not interested in knowing what a tree looks like if grown in infertile soil and left unsprayed or neglected. He is not going to grow them that way in modern production.

THE FACTOR OF PRUNING

It is a well established fact that unpruned trees will come into bearing more quickly than pruned trees. Even a few fruits per tree, if grown well under good environmental conditions, may enable the breeder to discard some of the more obviously poor seedlings. Their relatively early removal will allow more air and space for adjacent trees, reduce the cost of cultural care, and conserve the efforts of the breeder. Much cutting back or even thinning-out pruning of young seedlings for the first 5 years should be avoided. A young seedling apple will often fruit first on a central leader if it is allowed to grow unpruned. After the trees attain good bearing age and considerable culling of trees has taken place, then the more worthy trees should receive the approved standard pruning for the region.

EVALUATION AND SELECTION OF THE PROGENY

When the trees attain bearing age the evaluation and selection of the progeny begins. This requires the services of someone who is an expert in observing and interpreting plant characters and plant responses to environmental factors. The observations and data necessary to evaluate accurately a new seedling apple can be classified under two heads: (a) "Single Characters"; and (b) "The Tree as an Entity".

Single Characters:—As soon as any considerable number of the seedlings begin to bloom and ripen a few fruits, the study of single characters can be undertaken. Examples of these are fruit spur type; leaf vigor and resistance to scab; flower vigor; time of bloom; fertility; fruit size, form, and color; edible quality; and season of ripening.

The Tree as an Entity:—The nature and behavior of the tree as a unit is more important than any single character previously illustrated. It usually requires a longer period of observation, however, before the tree as a unit can be rated. Examples of characters to be determined are tree vigor, habit, and production; hardiness; growth status; temperature requirements and limitations; soil type preferences; and nutrient response class.

The range in variation of tree characters is much greater in the apple than in the peach. When crosses are made between standard varieties of peach the great majority of the progeny are trees of a normal size and are relatively prolific. The size of the progeny of a single cross of two apple varieties may vary from a bush form, with a height and spread not exceeding 5 feet after 12 seasons of growth, to trees that will eventually become as large as McIntosh. Small leaf types are often represented, the trees of which are fairly large but non-fruitful. Trees with more or less burr-knot are common in some crosses. Trees which form few if any spurs and fruit only on terminals are not unusual.

Should these latter trees be retained or discarded if the fruit characters are satisfactory? They are sometimes much more vigorous on Hibernal rootstock than when grown on their own roots.

It is important to learn as early as possible whether a new seedling tree of any commercial promise fruits largely on long spurs like Rome, on short spurs like Roxbury, or on a mixture of long and short spurs like McIntosh. Does it fruit on terminals and axillaries? Are the leaves relatively large, leathery, and thick like King or Summer Rambo, or relatively small like Winesap at New Brunswick? Are the leaves of a new variety resistant to low spring temperatures and do they function well at 40 to 45 degrees F like Baldwin or do the leaves developed early tend to turn yellowish green like Rome and Golden Delicious? It should always be remembered that the juvenile growth of some seedling apples may be different from the adult growth of the same tree.

Observations of the trunks of seedling apples near the collar or soil line at the New Jersey Station have often revealed whether or not the trees are susceptible to collar injury.

RESPONSE TO SEASONAL VARIATIONS

In a location like New Brunswick, New Jersey, an apple breeder has no cause to complain that he is unable to determine the response of a new apple to relatively low as compared to relatively high summer temperatures. In some seasons the fruits of McIntosh do not color well because of too high temperatures in late summer while in the next season the fruits may be rather highly colored because of a much cooler period.

Experience at New Brunswick has indicated that it is unwise to judge the merits of a variety by one season's behavior.

FLOWER CHARACTERS

There are many flower characters about which information is desired before selections should be made. These include relative time of blooming, fertility, and the ability to set and produce a crop of fruit.

FRUIT CHARACTERS

A few of the fruit characters which should be determined before a new seedling is given a merit rating include size and form; skin color, texture, and finish; flesh texture and color; season and rate of ripening; and edible quality fresh, cooked, baked, and in the form of expressed juice.

The fruits of some seedlings at New Brunswick varied as much as 10 days in their time of ripening in 1945 as compared to 1946 and yet other seedlings in the same cross ripened at about the same date in both years. This is a response to temperature indicator which should be utilized in selection work.

Another unusual feature of fruit behavior was observed in 1946. All of the apples in the tops of some dwarf type seedlings were distinctly conical in shape while all of the fruits in the lower halves of the same trees were distinctly oblate.

If the apple breeder is to evaluate the merits of new seedlings as thoroughly and as quickly as possible and thus shorten the long period of time in apple breeding, he must give attention to the many factors of propagation and orchard culture and to the tree response to basic environmental factors as well as to tree and fruit characters.

Budding and Grafting Eastern Black Walnut

By S. B. Chase, *Tennessee Valley Authority, Norris, Tenn.*

Black walnut can be successfully propagated by budding and grafting, although survival with either method is characterized by unaccountable seasonal and yearly variations. At the Norris Nursery named varieties are propagated in the spring by the modified cleft graft method and summer patch budding. Over a 12-year period survival with the Thomas variety has averaged 50 per cent for budding and 58 per cent for grafting (6). Budding is preferred because it is more economical and because it produces a more desirable tree. The studies reported here were designed to determine whether spring budding could be successfully substituted for grafting and to study a possible cause for erratic grafting results.

Spring Budding

Materials and Methods:—In a large block of vigorous Thomas seedlings, 2 years from seed, five uniform rows were selected for use. Thirteen plots of 10 uniform seedlings each were established in each row and the various budding methods to be employed were assigned to plots at random. Seedlings averaged 1.2 centimeters in diameter at the budding zone, approximately 2 inches above ground level.

Four budding methods were used: (a) ***skin bud,*** a method used on small nursery pecans, described by Adriance and Brison (1); (b) ***patch bud,*** using the Jones patch-budding tool described by Reed (3); (c) patch bud with wood, as in (b) except that after the cut was made on the budwood with the budding tool one side of the patch was lifted and with a knife a sliver of xylem with the bud trace was removed with the patch; and (d) the common ***shield bud.***

The following methods of tying and bud covering were used: waxed cloth strips ⅜ by 18 inches; rubber budding strips $^3/_{16}$ by 5 inches, bud waxed; rubber budding strips ⅜ by 7 inches; and rubber budding strips ⅜ by 7 inches, bud waxed. With the waxed cloth and the ⅜-inch rubber strips it was possible to completely cover the patch. This was not possible with the $^3/_{16}$-inch rubber strips because of their short length. The wax used was a combination of beeswax, rosin, and linseed oil.

Budwood was collected from 1-year-old Thomas grafts in the nursery in February 1942, graded for uniformity and stored in moist sphagnum at 38 to 40 degrees F. Budwood for patch budding was seasoned at 85 degrees F, as recommended for pecan by Brison (2). Dormant budwood was used for the skin and shield buds.

Skin budding, the only method of the four suitable for use on dormant stock, was begun approximately a month before stocks made any growth and was repeated at 2-week intervals until stocks began active growth. At this time all four budding methods were used.

After budding, the current growth of the stocks was topped when it became apparent that bud and stock had united. When the bud showed growth activity the balance of the stock above the bud was removed. With the four early skin budding operations the stock was reduced on May 4 and entirely removed May 16. The waxed cloth and rubber strips were removed when the buds had made 1 to 2 inches growth.

Results:—Results of the four budding methods are presented in Table I. Skin buds put on before the stocks were making active growth gave very poor results. Skin budding on May 4 to 6, 1942, after the stocks had grown 3 to 6 inches, resulted in fair to good survival. There was no statistical significance between the three tying methods used May 4 to 6 on skin buds.

TABLE I—EFFECT OF SPRING BUDDING METHOD ON BUD SURVIVAL

Date of Operation	Type of Bud	Tying Method	Survival of Fifty Buds* (Number)
Mar 25	Skin bud	Waxed cloth	1
Apr 8	Skin bud	Waxed cloth	5
Apr 15	Skin bud	Waxed cloth	8
Apr 15	Skin bud	3/16 inch rubber waxed	0
May 4	Skin bud	Waxed cloth	11
May 4	Skin bud	3/16 inch rubber, waxed	15
May 5	Patch bud	⅜ inch rubber	24
May 5	Patch bud	⅜ inch rubber waxed	20
May 5	Patch bud with wood	⅜ inch rubber	12
May 6	Skin bud	⅜ inch rubber	20
May 6	Shield bud	⅜ inch rubber	2

*Minimum difference significant at P = 5 per cent = 11, 1 per cent = 14

Patch budding gave better results than any of the other methods. Patch buds with wood resulted in only one-half the survival obtained by using the normal patch bud. Waxing patch buds after tying with ⅜-inch rubber strips lowered the survival slightly.

Shield budding and tying with ⅜-inch rubber strips resulted in a 4 per cent survival, the lowest for any of the methods used on actively growing stocks. This method does not lend itself well to black walnut propagation. The size and shape of the bud which can be cut from scions is such that it is difficult to get good contact with the stock.

SPRING GRAFTING

It has been reported by Roberts (4) that the position of the top bud of scions influences the stand and growth of apple grafts. To determine whether top bud position could be a factor in grafting black walnut and to study the effect of using short scions, the following experiment was conducted.

Materials and Methods:—Four uniform rows of vigorous Thomas black walnut seedlings, 2 years from seed, were used in these grafting studies. Each row was divided into seven plots of 10 uniform seedlings each and the grafting treatments described below were assigned at random to plots in each row. Thomas budwood was collected in February from vigorous 1-year-old grafted trees growing in the nursery, graded for uniformity of size, and stored in damp sphagnum at 38 to 40 degrees F. As the buds on the stocks began to open the stocks were cut back to 3 inches. When bleeding ceased 2 weeks later they were grafted with scions having top buds in different positions (Fig. 1), in relation to the cleft, as follows:

1. Basal bud in cleft with no control over the position of the top bud (usual method, control).
2. Top bud in line with middle of cleft on the unmatched side of the cleft (opposite to position No. 4).
3. Top bud in line with the larger lip of the cleft (opposite to position No. 5).
4. Top bud in line with the middle of cleft on the matched side of cleft (opposite to position No. 2).
5. Top bud in line with the smaller lip of the cleft (opposite to position No. 3).
6. *One-bud scion.* Bud in line and just above the cleft.
7. *Two-bud scion.* Basal bud in cleft with no control of top bud (similar to position No. 1 except for number of buds).

A modified cleft graft, illustrated in Fig. 1, was used in this study. The grafts were tied with raffia, waxed with a preparation composed of beeswax, rosin, and linseed oil, and shaded with a rectangular piece of cardboard. The position of each bud on each scion was recorded as the grafts were made on May 7, 1942. Scions of three or four buds each were used in all treatments except with Nos. 6 and 7 where the number of buds was specified as part of the treatment. The grafts were examined on June 3, 1942, and the bud growth was recorded in order of dominance. All but the dominant shoot was removed at this time and when the shoot from the top bud was not dominant, the scion was reduced to the dominant shoot.

Results:—The data presented in Table II show that the position of the top bud of the scion had no effect on the survival of black walnut grafts. Top buds, regardless of position, showed subsequent dominance better than 64 per cent of the time, in all positions except Nos. 1 and 5. In position No. 1, where the basal buds was always in the cleft, there was less tendency for the top bud to become dominant. Also, in position No. 5, where the basal bud accidently fell in the cleft 35 per

TABLE II—PERFORMANCE OF BLACK WALNUT GRAFTS WITH TOP BUDS OF SCIONS IN FIVE POSITIONS AND SCIONS OF DIFFERENT SIZES

Position of Top Buds	Successful Grafts	
	Survival of Forty Grafts* (Number)	Top Bud Showing Subsequent Dominance (Per Cent)
1. Basal bud in cleft, no control over top bud	38	44.7
2. Top bud in line with the middle of cleft on the *unmatched* side	37	64.9
3. Top bud in line with the *larger lip* of the cleft	39	66.7
4. Top bud in line with the middle of cleft on the *matched* side	38	71.1
5. Top bud in line with the *smaller lip* of the cleft	39	46.2
6. *One-bud scion.* Bud in line and just above the cleft.	35	—
7. *Two-bud scion.* Basal bud in cleft with no control over top bud	37	—

*Minimum difference significant at P = 5 per cent = 13 cent of the time, this same lessened tendency was evident. Dominance of buds of short scions is not reported as scions contained only one or two buds.

There was no difference in the survival of the one- and two-bud

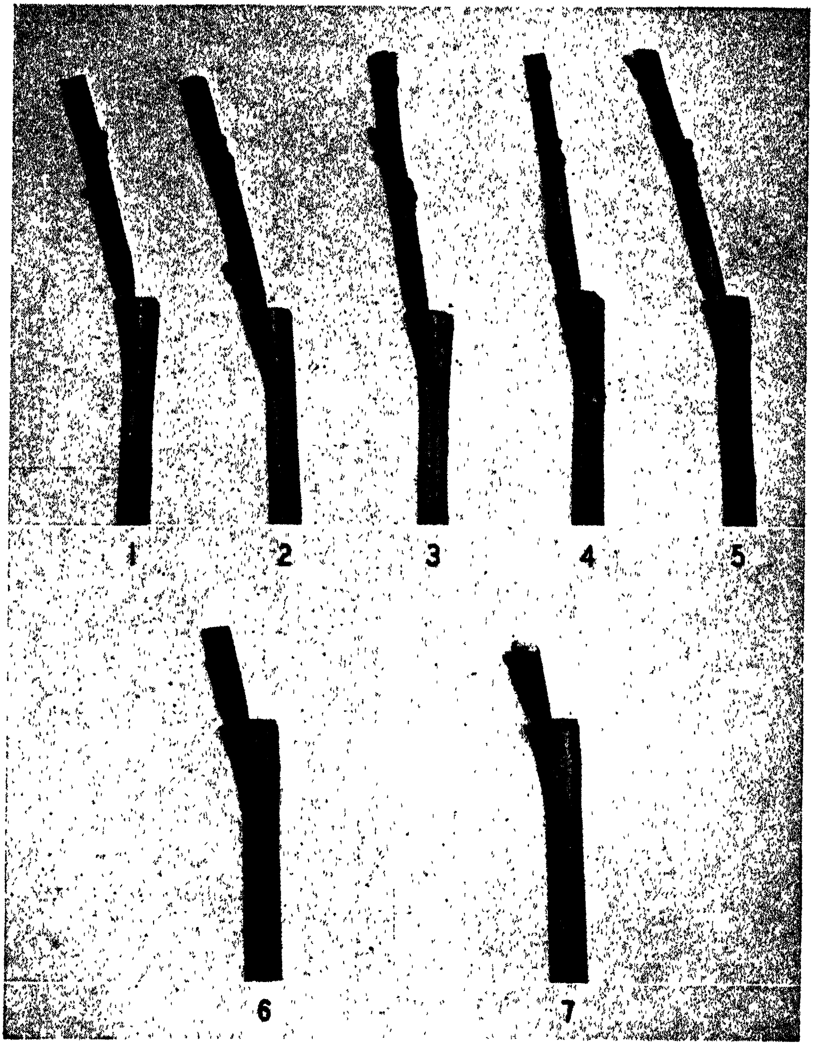

FIG. 1. Top bud positions on scions in grafting study. *Description of bud position:* 1, Basal bud in cleft, no control over position of top bud; 2, Top bud in line with middle of cleft on unmatched side of cleft; 3, Top bud in line with larger lip of the cleft; 4, Top bud in line with the middle of cleft on matched side of cleft; 5, Top bud in line with the smaller lip of the cleft. *Short scions:* 6, One-bud scion, bud in line and just above cleft; 7, Two-bud scion, basal bud in cleft with no control of top bud.

scions as both produced high graft survival (Table II). Trees produced from these scions were straighter, lacking the undesirable crook which generally results from using long scions.

DISCUSSION

Black walnut has a strong flow of sap in early spring and the profuse bleeding which occurs when the stock is cut preparatory to grafting is often regarded as one reason for failure. Bleeding can be controlled in grafting by cutting back the stocks as growth starts. Bleeding continues for 10 to 14 days and when it ceases the stocks are grafted. In the budding study no attempt was made to control bleeding. Considerable bleeding did occur and probably accounted for most of the failures on those stocks budded May 4 to 6. The poor survival of patch buds with wood was attributed to the presence of xylem and bud trace on those buds which probably interferred with bud union. Waxing the bud after insertion on the stock did not increase survival which indicates that bud desiccation was not a cause of bud failure.

Skin budding requires more time than patch budding because cambium layers must be matched on at least one side. The method is useful, however, on smaller stocks which fail to attain sufficient diameter for patch budding the previous summer or for spring grafting. Realizing that skin budding as early as a month before stocks begin active growth might be too early for good results, it was desirable to determine just when budding could begin for purposes of spreading the budding season. It was rather cold with several light freezes during the period March 25 to April 15, 1942, when this early budding was done. The poor early skin bud survival was attributed to the low temperature which prevailed; Sitton (5) has reported that warm temperature, approximately 82 degrees F, is of primary importance for callus formation in black walnut.

The position of the top scion bud reported as having a bearing on survival and growth of apple grafts (4) apparently has no significance in black walnut grafting. High survival resulted regardless of top bud position. Neither was there any noticeable difference in the size of grafts produced. Trees were uniformly large, many reaching a height of 10 feet.

Three- or four-bud black walnut scions from vigorous budwood are usually 4 to 6 inches long. Using the modified cleft graft the scions are set in the stocks at the angle shown in Fig. 1. The general tendency of the top bud to make the most vigorous growth and its selection to form the tree often results in structurally weak graft unions. Use of short scions containing two buds may overcome this structural weakness. Survival of short scions used in this study was comparable to that of three- and four-bud scions and the trees were consistently better formed. One-bud scions showed no advantage over two-bud scions. Since there is always a possibility of losing one bud, use of single-bud scions leaves no alternative and hardly seems advisable under nursery conditions. Whether the basal bud of scions was in the center of the cleft or otherwise had no effect on survival of grafts.

The high average graft survival of 94 per cent obtained in this study is unusual in the propagation of black walnut. The test itself furnishes no clue to this high survival unless it resulted from the highly favorable conditions which prevailed throughout. Budwood was carefully selected for uniformity of size and vigor and the stocks were uniformly large and vigorous. Weather conditions during and following grafting were ideal. Black walnut is a difficult species to propagate. Careful selection and handling of scions and stock are essential for successful grafting.

The spring budding studies were preliminary in nature and involved only slight variations. Patch budding offers most promise as a spring budding method under Tennessee conditions. Patch bud survival in these tests approaches that of average summer patch bud survival but was much lower than grafting using comparable budwood and stock. Unless by refinement of technique survival can be increased, spring budding does not appear to be a satisfactory substitute for spring grafting.

SUMMARY

Four methods of spring budding black walnut were compared. Skin budding on dormant stocks resulted in poor survival. There was no significant difference between patch budding and skin budding on actively growing stocks. Patch budding was found to be the best and fastest method. Shield budding was almost a complete failure. Completely waxing buds after tying showed no advantage. Cold weather and bleeding of stocks are offered as causes of bud failure. Budding resulted in only approximately half the survival secured by grafting.

The position of the top scion bud had no effect on the survival or growth of black walnut grafts. Growth of shoots from the top buds was more vigorous than from other buds regardless of their position. One- and two-bud scions produced more desirable trees than longer scions.

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A Strain of McIntosh Compatible with Virginia Crab Stocks

By J. A. McClintock, *Purdue University, Lafayette, Ind.*

McIntosh apple trees propagated on French Crab seedling stocks vary in tree growth and fruit production. Data collected over a number of years by the writer indicate that some McIntosh trees on French crab seedling stocks are conspicuous for the production of a high percentage of small fruits.

The writer having established through research (1) that the Grimes variety in Indiana could be improved in uniformity of tree growth and increased size of fruit extended his studies to other commercial varieties including McIntosh.

The strain of McIntosh used in these studies was obtained from a reliable source, where it had proved satisfactory in color at maturity. No difficulties were encountered in propagating this strain of McIntosh on own-rooted Virginia Crab stocks in the test nursery, or as scaffold-worked trees in the orchard plots. In the orchard plot this strain of McIntosh made a vigorous vegetative growth and was surpassed in growth only by Golden Delicious and Turley (2).

Strains of McIntosh differing in red coloring of the fruit have been recognized and propagated commercially for some time, but Tukey and Brase (3) in 1943 were the first to report strains of McIntosh lacking in compatability. Their evidence is conclusive that the strain of McIntosh used in the New York tests is uncongenial when top-worked on Virginia Crab.

These contradictory New York and Indiana results with the McIntosh variety top-worked on the clonal stock Virginia Crab indicate that strains of McIntosh exist which differ greatly in compatibility.

In this report the writer presents additional data regarding the compatible strain of McIntosh used in the Indiana studies. The McIntosh trees set in the Indiana planting in 1936 were bearing fruit in 1943 when the New York results on uncongeniality of McIntosh top-worked on Virginia Crab were published. Because of the New York findings, the writer has studied the Indiana plantings carefully for the past three years to determine whether delayed symptoms of uncongeniality would develop. Up to the close of the 1946 growing season no such symptoms have been manifested. This strain of McIntosh has grown vigorously and has continued to bear increasing yields of fruit.

In addition to its congeniality, the strain of McIntosh used in the Indiana studies has responded to the superior understock in fruit production. Yield records during the years 1942 to 1946 showed the average size of these McIntosh fruits to be larger on the trees with own-rooted Virginia Crab understocks.

Fruits from McIntosh trees propagated by conventional methods on French Crab seedlings ranged from 2 $^{5}/_{16}$ to 3 $^{10}/_{16}$ inches, with an average diameter of 2$^{12}/_{16}$ inches. Fruits from McIntosh top-worked on own-rooted Virginia Crab measured from 2$^{8}/_{16}$ to 3$^{13}/_{16}$ inches, with an average diameter of $3^2/_{16}$ inches. When converted to the number of fruits per bushel these size differences averaged 128 fruits of McIntosh grown on top-worked Virginia Crab Clons, and 163 fruits when grown on French Crab seedlings. This difference in size is conspicuous; and in markets where a 3-inch McIntosh commands a premium, this stock influence would prove a distinct advantage to commercial growers.

The writer presents these Indiana studies in order to advance the solution of one of the major problems which face those engaged in root-stock improvement.

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The Relative Color Stability of the Wines of Certain Grape Varieties

By M. A. AMERINE and A. J. WINKLER, *University of California, Davis, Calif.*

THE tendency of red wines to deposit considerable amounts of sediment while in the bottle is a troublesome feature of their finishing and marketing. This is particularly true in California where commercial demands frequently necessitate very early finishing and bottling of wines. These deposits represent not only precipitates due to direct oxidation during bottling but also to polymerizations and other causes during aging in the bottle in the relative absence of oxygen. The deposits which occur during the early bottle life of the wine are particularly objectionable. The trade, at least partially, recognizes that in giving the best wines bottle age some deposition is inevitable. Even so, it is a practice in certain parts of France to siphon red wine off the deposit from aged bottles before shipment to the United States.

Of two varieties of equal quality the wine maker would thus naturally prefer the one which had the least deposition of color during aging. These experiments were designed to measure the relative tendency of various varieties to deposit their color.

EXPERIMENTAL

The wines reported on here were produced during the 1936, 1937, and 1938 vintage seasons. They were first analyzed about January 1 of the year following their production and then again in March, 1946. The wines were aged in wood (5- or 10-gallon oak barrels) for 8 to 16 months and then bottled. The 1946 analyses were therefore made on wines which had been in the bottle from about 7 to 9 years. Details of the methods of collection, fermentation, and analysis have been published elsewhere (1).

Only nine varieties were selected for analysis in 1946. The grapes were from various parts of California, representing most of the wine-grape-growing climatic regions of the state.

Table I gives the three-year summary of each of the nine varieties, except that the Grand noir was collected only in 1936 and 1937.

Table II gives a summary for all of the varieties for each season and a grand average.

DISCUSSION

These varieties may be ranked according to their per cent loss in color.[1] Based on the figures obtained with the Dujardin-Salleron vinocolorimeter, the order from greatest to least color loss was: Alicante Bouschet, Grand noir, Petite Sirah, Charbono, Zinfandel, Barbera, Carignane, Cabernet Sauvignon, and Valdepenas. The order based on the per cent loss as measured by the color standards was: Alicante

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[1] It is recognized, of course, that the calculation of the per cent loss in color is empirical. It is, however, comparable from one variety to another and does give a picture of relative color stability.

TABLE I—COLOR AND TANNIN CHANGES IN 1936, 1937, AND 1938 FROM PRODUCTION TO 1946

Original	No. Samples	Color Value By						Tannin		
		Vinocolorimeter			Color Standards					
		Original	1946	Per Cent Loss	Original	1946	Per Cent Loss	Original	1946	Per Cent Loss
Alicante Bouschet..	18	4VR-50.6	2R- 9.4	81.4	861	263	69.4	0.22	0.18	17.4
Barbera...	9	5VR-26.2	3R- 8.2	68.7	374	201	46.3	0.15	0.14	11.6
Cabernet Sauvignon	29	4VR-27.1	3R- 9.5	64.9	326	236	27.6	0.16	0.13	16.1
Carignane.........	42	5VR-17.2	3R- 5.4	68.6	217	136	37.3	0.11	0.09	17.7
Charbono.........	10	4VR-27.3	3R- 8.1	70.3	408	215	47.3	0.16	0.13	17.9
Grand noir	8	5VR-27.3	3R- 7.0	74.4	405	186	54.1	0.17	0.13	20.1
Petite Sirah........	55	4VR-44.4	R-12.5	71.8	633	349	44.9	0.24	0.20	18.7
Valdepenas..	16	5VR-17.7	3R- 6.8	61.6	203	167	17.7	0.18	0.15	16.9
Zinfandel..........	38	5VR-20.7	3R- 6.3	69.6	255	158	38.0	0.16	0.13	17.3

TABLE II—COLOR AND TANNIN CHANGES IN NINE VARIETIES FOR THE 1936, 1937, AND 1938 SEASONS

Year	No. Samples	Color Value By						Tannin		
		Vinocolorimeter			Color Standards					
		Original	1946	Per Cent Loss	Original	1946	Per Cent Loss	Original	1946	Per Cent Loss
1936	54	4VR-40.9	2R- 8.1	80.2	754	264	65.0	0.21	0.17	18.4
1937	95	5VR-24.9	3R- 8.2	67.1	304	212	30.3	0.16	0.13	18.6
1938	61	4VR-29.4	3R-10.0	66.0	302	230	23.8	0.19	0.16	15.4
Average	210	5VR-30.3	3R- 8.7	71.3	422	230	45.5	0.18	0.15	17.9

Bouschet, Grand noir, Charbono, Barbera, Petite Sirah, Zinfandel, Carignane, Cabernet Sauvignon, and Valdepenas.

It may be noted that the per cent loss as measured by the color standards was somewhat less than by the vinocolorimeter. The order of the varieties, however, was essentially the same. Thus, the Alicante Bouschet and Grand noir showed the greatest color loss while the Cabernet Sauvignon and Valdepenas had the least. This would tend to collaborate plant observations on the undesirability of bottling wines made partially or wholly from Alicante Bouschet or other varieties of Tienturier parentage because of the relatively rapid and large color deposition from their grapes.

The relative color instability of the Alicante Bouschet is further indicated by comparing its 1946 color values, using color standards, with, say, the Cabernet Sauvignon. At the present time each have about the same color value. When they were first analyzed the Alicante Bouschet had over two times as much color. Thus Alicante Bouschet and related varieties, irrespective of their other dubious qualities, are poor varieties to use for permanently increasing the color intensity of wines produced from other grapes.

The color changes for the years 1936, 1937, and 1938 listed in Table II are also of considerable interest. They show the relatively greater color loss of the 1936 wines compared to the 1937 and 1938 wines. The 1936 season was very warm, and the grapes were much riper. (The average alcohol content for the 1936 samples averaged 13.5 compared to 12.0 and 12.1 for the other two years). The skins were thus subject to extraction by a higher alcohol content during fermentation. Apparently a larger percentage of precipitable coloring materials were extracted.[2] The present color values for the three years is approximately the same; in fact, by the vinocolorimeter the 1938 wines are the better colored at present.

The tannin losses show no particular differences between varieties or years. Something less than 20 per cent of the tannin is lost during seven to nine years' aging in the bottle.

CONCLUSION

Marked differences exist in the color stability of wines produced from different varieties and from grapes of different seasons in California. This is in addition to the inherent differences in quantity of color found in the various varieties or that produced in the grapes in different seasons. In general, the greater the original intensity of color the greater the percentage loss during aging.

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[2] The greater color values shown here for the 1936 season do not conflict with previously published results (2) on the effect of warm years on the color pigments. For wines of *the same alcohol content* the 1936 wines had less color.

Breeding Studies in Eastern States with the Western Trailing Blackberries

By GEORGE M. DARROW, C. F. WILLIAMS, and GEORGE F. WALDO,
Bureau of Plant Industry Station, Beltsville, Md.

SOME of the finest flavors in the blackberry-dewberry group are in the wild trailing blackberries of the Pacific Coast region. Many are acquainted with the flavor of the Logan (Loganberry), Young (Youngberry), and Boysen (Boysenberry). Some know the even finer-flavored Cascade and Pacific. These varieties inherit their flavors in part at least from the native trailing Pacific Coast blackberry.

The Logan has not succeeded in the eastern United States. The Young and Boysen are well adapted to the areas from southern Virginia to southern Georgia and west to Oklahoma and Texas, but are not hardy in northern States.

Extensive breeding work with the western trailing blackberries is being carried on at Corvallis, Oregon, and the Cascade and Pacific have resulted from that work. Because the diseases affecting varieties and climatic responses of the varieties differ so greatly in the two regions, the results obtained in western Oregon are not applicable to the eastern United States.

In an attempt to obtain varieties of higher dessert quality adapted to eastern and northern States, a series of crosses of adapted eastern varieties and varieties derived from the western trailing blackberry were made in Oregon and the seed sent to Beltsville, Maryland. The resulting seedlings were planted partly at Beltsville (June 1942) and the rest at Willard and Raleigh, North Carolina (fall 1942). The seedlings at Beltsville were large enough to fruit in 1944 when the selections were made, and the remainder discarded. Approximately the same number of seedlings of the crosses with Lucretia as of those with Eldorado were potted up. Many seedlings with Eldorado as one parent died in the pots or soon after planting in the field. Seedlings distinctly dwarfed while in pots were discarded. Many of the seedlings after planting proved to be dwarfs and either died or were hoed out. Only plants making normal canes in the field were left to fruit. Table I gives some results of the test at Beltsville, Maryland.

TABLE I—NUMBER SEEDLINGS PLANTED, NUMBER SURVIVING, AND NUMBER OF SELECTIONS MADE OF BLACKBERRY CROSSES AT BELTSVILLE, MARYLAND, JUNE 29, 1944

Cross	Chromosome Numbers	Number Alive Aug 1942	Number Alive Jun 1944	Number Selections
Hunter ×Lucretia	12×6	448	348 (78 per cent)	6
Zielinski ×Lucretia	12×6	464	271 (58 per cent)	1
Zielinski ×Eldorado	12×4	301	99 (33 per cent)	0
Pacific ×Lucretia	9×6	485	407 (84 per cent)	12
Ideal Wild ×Eldorado	8×4	103	54 (52 per cent)	2
Ware ×Eldorado	8×4	203	60 (30 per cent)	0
Starr ×Lucretia	8×6	454	170 (37 per cent)	2
Starr ×Eldorado	6×4	249	35 (14 per cent)	0
Total		2,707	1,444 (53 per cent)	23 = 1 per cent
Lucretia crosses		1,851	1,196 (65 per cent)	21 = 2 per cent
Eldorado crosses		856	248 (29 per cent)	2 = 1 per cent

The most striking characteristic of the crosses was the relatively high survival after planting in the field of the seedlings from crosses with Lucretia as the pollen parent (65 per cent) as contrasted with the low survival of the seedlings from crosses with Eldorado as the pollen parent (29 per cent). On the basis of equal numbers of seedlings potted up, the Lucretia seedlings had a 65 per cent survival as compared with 15 per cent survival of Eldorado seedlings. Lucretia has trailing canes as do the various seed parents, while Eldorado is erect growing. However, the canes of Lucretia are considered much less hardy than those of Eldorado. The poor survival of the Eldorado crosses may be due to genic composition, or to its lower chromosome number. It is quite possible that there is a differential survival rate between seedlings of higher and of lower chromosome numbers. At least the available evidence points to this conclusion. Waldo in Oregon has obtained productive seedlings when both parents have high chromosome numbers. This has been true even though the chromosome number of the seedlings is uneven. Two of his selections resulting from crosses of varieties of 12 by 6 chromosome complement have been named Cascade and Pacific.

Of the 23 Beltsville selections, none was outstanding in comparison with Boysen or Young, either in vigor of plant or in fruit characteristics. Most were distinctly inferior in disease resistance of foliage and cane, and in size of berry. Most had good flavor, some high flavor. A few seemed distinctly more hardy and were productive enough to offer some little encouragement to continue their use in breeding.

In North Carolina the crosses set and number saved are given in Table II.

TABLE II—Number Seedlings Planted, Number Surviving, and Number of Selections of Blackberry Crosses in North Carolina

A

Crosses at Willard	Chromosome Numbers	Number Set	Number Alive	Number Selections
Hunter ×Lucretia	12×6	876	523	1
Zielinski ×Lucretia	12×6	864	540	0
Pacific ×Lucretia	9×6	1,044	552	3
Starr ×Lucretia	8×6	1,056	590	0
Total		3,840	2,205 (57 per cent)	4

B

Crosses at Raleigh	Chromosome Numbers	Number Set	Number Recorded	Number Selections	Productive and Fertile
Elmer Johnson ×Lucretia	8×6	378	173	9	16 (9 per cent)
Pacific ×Himalaya	9×4	290	157	4	12 (8 per cent)
Total		668	330	13 (4 per cent)	28 (8 per cent)

The seedlings at Willard did not survive quite so well as those in Maryland but the field at Willard was not well drained. At Raleigh fewer seedlings were planted and the crosses were not related. Very few (8 per cent) seedlings bore fully formed berries but more selections were made than at Willard.

Additional crosses made in attempting to obtain hardier varieties have been with Boysen at Beltsville, Maryland, as follows:

	Approximate Number	
	Seedlings	Selected
Boysen (6x) ×Austin Thornless (8x)	85	0
Austin Thornless (8x) ×Boysen (6x)	35	0
Boysen (6x) ×Brainerd (4x)	10	1
Eldorado (4x) ×Boysen (6x)	156	1
Total	286	2

Most of these seedlings were nearly sterile. Two selections — one Boysen by Brainard, and one Eldorado by Boysen — seem hardier than Boysen and are being given row tests.

Though no varieties adapted to eastern States have yet resulted from this breeding work, some progress seems to have been made. If the results with the lower chromosome crosses in Rubus continue to hold, it would seem that in making intergroup crosses every effort should be made to use the varieties with high chromosome numbers. Thus, instead of the hexaploid Lucretia the use of the octoploids Premo and Windom would seem worth trying, and instead of the tetraploid Eldorado it might be worth while using the hexaploids Rathburn and Erie. Waldo in Oregon has obtained his best selections from 12x × 6x crosses (unpublished records).

A Polyploid Chromosome Series from a Cross of the Lawton Blackberry and the Nessberry

By S. H. YARNELL and H. T. BLACKHURST, *Agricultural and Mechanical College of Texas, College Station, Tex.*

THE Nessberry is one of the first amphidiploid plants to appear in pedigree culture. It was found by Ness (4) in 1917 in a segregating second generation of a cross between *Rubus rubrisetus* x Brilliant red raspberry. The cytological status of the Nessberry was first recognized by Longley and Darrow (3) in 1924, who found 14 pairs of chromosomes during meiosis. The plant propagated and introduced as the Nessberry was selected from the third generation, the variations of which, according to Ness, consisted "mostly in vigor of the shoots, size of the leaves, size and abundance of the fruit, and the time and length of the fruit period".

In order to improve its picking qualities the senior author grew 136 plants in 1938 from the Nessberry self pollinated. No marked improvement in this important characteristic was obtained. In order to secure segregation and a recombination of genes the Nessberry was crossed with the Lawton blackberry in 1944. According to Hedrick (2), Lawton was found near New Rochelle, New York, in 1834, and named in 1853. Fischer, Darrow and Perlmutter (1) list the variety as having 28 somatic chromosomes. It is one of the leading varieties in commercial production in Texas.

All flowers of a single plant were either emasculated or picked off and pollinations were made directly from a flower of the other parent. The flowers were left unprotected because of the poor set of fruit under bags. Some flowers were left unpollinated as a check. Two or three achenes developed under the latter conditions, although most of the unpollinated flowers dropped.

Twenty-four plants were obtained when Lawton was used as the seed parent and a single plant from the reciprocal cross. The latter is a hybrid with 28 somatic chromosomes. Of the former there are four small plants with 14 somatic chromosomes, four vigorous triploids, 11 tetraploids similar in appearance to the Lawton parent, four plants with the tetraploid chromosome number, obviously hybrid, and a single plant with 35 chromosomes, also hybrid in appearance (Table I). Fig. 1 illustrates characteristic leaves of the parents and of the five types found in the first generation.

Plants with the diploid chromosome number are very much dwarfed and vary among themselves in vigor and in fertility. The seeds and fruit of No. 64–15 are nearest the normal in size and appearance. The achenes of No. 64–17 never developed any flesh and the seeds are so small as to be of doubtful viability. Plant No. 64–7 bloomed but set no fruit; No. 64–9 did not produce any bloom and at the end of its second season is in very poor condition.

Three plants with the triploid chromosome number are considerably more vigorous than either parent, while the other one is about the same as Lawton in this respect. The size of the fruit is reduced, but the achenes that develop are normal in appearance. The leaflets are

TABLE I—FIRST GENERATION OF THE LAWTON-NESSBERRY CROSS

Ped. No.	2n Chromosome	Type Plant	Fruit Set	No. Seeds Per Fruit	Pollen (Per Cent)			Notes
					Good	Bad	Giant	
Ness	28	———	Good	—	76	24	0	
Lawton	28	———	Good	—	88	12	0	
64–7	14	Small	Poor	0	32.0	67.0	1.0	Weak; no seeds
64–9	14	Small	None	0	—	—	—	Did not bloom
64–15	14	Small	Fair	22.4	20.0	77.5	2.5	Seeds large
64–17	14	Small	Fair to poor	6.1	6.5	93.5	0.0	Seeds very small, fruit dry
64–11	21	Hybrid	Poor	1.8	23.5	76.5	0.0	
64–13	21	Hybrid	Fair to good	19.2	—	—	—	Very vigorous
64–14	21	Hybrid	Fair to good	12.5	34.5	65.5	0.0	Very vigorous
64–16	21	Hybrid	Fair to good	18.4	—	—	—	Very vigorous
64–1	—	Lawton	Good	—	67.5	32.5	0.0	
64–2	—	Lawton	Good	—	79.0	21.0	0.0	
64–3	—	Lawton	Good	43.6	82.0	18.0	0.0	
64–4	—	Lawton	Good	55.4	—	—	—	
64–5	—	Lawton	Good	48.6	86.5	13.5	0.0	Fruit larger
64–6	28	Lawton	Good	—	—	—	—	
64–8	28	Lawton	Good	—	88.5	11.5	0.0	
64–10	28	Lawton	Good	22.7	74.5	25.0	0.5	
64–21	28	Lawton	Poor to fair	—	64.0	36.0	0.0	
64–23	28	Lawton	Good	—	79.5	20.5	0.0	
64–24	—	Lawton	Good to fair	18.2	—	—	—	Less vigorous
63–1*	28	Hybrid	Fair	—	61.0	38.5	0.5	Nearer Nessberry
64–12	28	Hybrid	———	11.8	—	—	—	Nearer Nessberry bloomed late
64–18	28	Hybrid	———	0	—	—	—	Little or no bloom
64–19	28	Hybrid	Fair to good	22.7	—	—	—	Vigorous, bloomed late
64–22	28	Hybrid	———	10.9	—	—	—	Nearer Nessberry
64–20	35	Hybrid	Poor to fair	11.6	42.0	56.0	2.0	Procumbent

*Ness ×Lawton; the rest have Lawton as seed parent.

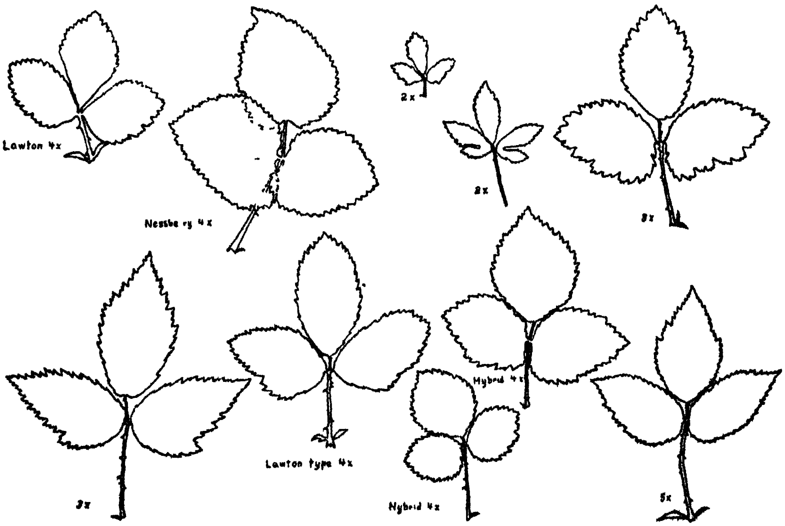

FIG. 1. Outlines of leaves of the parents (Lawton and Ness) and of the five types found in the first generation.

somewhat longer and the serrations coarser than those of either parent. In general aspect the plants favor the Lawton variety. The percentage of good pollen is about the same as in the most normal of the 2x plants.

While the 11 "maternal" type plants show definite points of difference, there is no indication of Nessberry influence. Two of them (64–21 and 64–24) have reduced fertility as judged by fruit set. The first of these has somewhat less good pollen; the other is less vigorous. Plant No. 64–10 also has fewer seeds per fruit and was observed to have 0.5 per cent of giant pollen grains. The first five are so uniform that chromosome counts were not made, but there is every reason to believe that they have the 4x number.

All of the 4x hybrids can be considered together. They are much alike in general appearance, favoring the Nessberry in leaf shape and venation, and in habit of growth. The plants seem to vary a great deal in fertility. As these results are for only their first fruiting season they may later tend to become more nearly alike in this respect, especially since three of them were slow to bloom

Except for the dwarf 2x plants the pentaploid is most distinctive in appearance In habit of growth it is procumbent. The leaves are like those of the triploids The vines have a distinctive reddish-purple coloration early in the season. The fruit is more like that of the Nessberry than in the case of the other hybrids.

The possible origin of the different types is of interest in estimating their value as parents for a second generation. The nature of the cross was such that nothing of horticultural value was anticipated before the second or later generations The simplest explanation for the appearance of the dwarf 2x plants is the stimulation of a reduced egg by pollen from the Nessberry without fertilization. Their similarity suggests that the Lawton is an auto-tetraploid. The variation observed is no more than might be expected from a heterozygous parent. A later doubling of chromosomes in this type of plant would give a Lawton fully homozygous for 14 pairs of chromosomes.

There is good reason to suppose that the triploids resulted from the union of an egg of Lawton with 14 chromosomes, the normal number, with 7 chromosome pollen from the Nessberry. In appearance they favor the Lawton parent. Yarnell (5) observed that during meiosis in the pollen mother cells of the Nessberry "the chromosomes seem to have some difficulty in forming a normal metaphase plate" of the heterotypic division. In addition, a spindle view of first anaphase illustrates 7 pairs dividing ahead of the other 7 pairs, indicating the possibility of 7 chromosome pollen grains. The 7 chromosomes in the pollen presumably represent all of the chromosomes in a basic set, either of the raspberry or the dewberry. Three of the triploids had a fair to good set of fruit with fairly comparable seed development. The other plant, No. 64–11, had a poor set of fruit with an average of less than two seeds per fruit. Regardless of whether the raspberry or dewberry set of chromosomes is represented in the triploid, this group of plants would seem to offer less opportunity for reaching the original objective of the cross than in the case of the tetraploid hybrids.

The simplest explanation for the appearance of the single pentaploid plant, No. 64–20, would seem to be the union of a 14-chromosome normal egg of Lawton with a 21-chromosome pollen grain from the Nessberry. The assumption of 7-chromosome Ness pollen in the production of the triploids, suggests that the remaining 21 chromosomes might at times organize some functional pollen. There may be a possibility of securing 4x seedlings with new desirable combinations from this pentaploid.

Most of the 11 Lawton type plants are evidently normal in fertility and differ from the seed parent in only minor respects. While accidental self pollination seems to be the most convenient explanation of these plants, the development of a reduced egg with a return to the normal chromosome number is not ruled out. The production of 2x plants from a reduced egg lends some credence to this possibility. If this has happened, such plants would be completely homozygous and could probably be detected in the second generation. Other forms of apomixis could, of course, explain this. Three of these plants bear further investiation from another standpoint. Plant No. 64–10 has fewer seeds per fruit and produced 0.5 per cent of giant pollen grains. This happened in only three other cases in the entire population: two 2x plants and the pentaploid. Plant No. 64–21 (Lawton type) had only a poor to fair set of fruit and a slightly reduced proportion of good pollen as compared to the others. Plant No. 64–24 had a slightly reduced fruit set and only 18.2 seeds per fruit instead of the 45 to 50 expected.

The appearance of the 4x hybrids is what might be expected from one set of raspberry chromosomes, one set of dewberry chromosomes and two sets of blackberry chromosomes. Plant No. 63–1, resulted from the pollination of the Nessberry with pollen from Lawton. The others are from the reciprocal cross (Table I). The degree of fertility, while much reduced in comparison with the Lawton type 4x plants, still would appear to offer the possibility of providing seedlings with new combinations and with increased fertility. The reduced size of fruit is the most serious horticultural defect of these 4x hybrids. Plants combining an intensified raspberry flavor with the picking quality of the blackberry and with adaptability to southern conditions will be selected. This might result from an increase in the proportion of dewberry chromosomes at the expense of certain of the raspberry chromosomes through meiotic irregularity. This should combine increased fertility with improved horticultural characters.

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Development Time from Bloom to Maturity in Cultivated Blueberries[1]

By J. S. Bailey, *Massachusetts Agricultural Experiment Station, Amherst, Mass.*

The determination of the correct stage at which to harvest various fruits is of such importance that it has received the attention of numerous investigators who have tried various methods for determining maturity. Among the most recent of these is that of elapsed time from full bloom to picking maturity. Several workers (4, 5, 6, 7) have suggested that in the case of apples, peaches, pears, and cherries this interval varies within narrow enough limits so that it can be used as a practical means of determining picking dates.

In applying this lapsed time method in determining maturity dates for cultivated blueberries, one is immediately confronted with the problem of determining the limits of the period. Both blooming and harvesting seasons are much longer for this fruit than for those previously mentioned. The blooming period lasts for 3 weeks or more in normal seasons. In long ones it may be 4 to 5 weeks. Even in short seasons it is seldom less than 2 weeks. Very often fertilized blossoms which had shed their corollas and unopened flower buds are found on the same bush at the same time. This makes it rather difficult to determine the time of full bloom. Nevertheless, the date on which the largest number of blossoms appeared to be open has been recorded for a number of years and called full bloom.

Since all the berries on a blueberry bush do not mature at the same time, several pickings must be made at about weekly intervals. Usually the picking season at Amherst lasts from 3 to 6 weeks, depending on the season, variety, and size of the crop. The question, then, is what date to select as the time of maturity. From a practical standpoint the date of first picking would seem to be the best time to select.

Using the date of full bloom and the date of first picking as limits, Table I gives the lapsed time in days for 10 varieties over a period of eight years.

TABLE I—Time in Days from Full Bloom to First Picking

Variety	1937	1938	1939	1940	1941	1942	1943	1946	Ave.	Maximum Difference
Cabot	44	60	46	56	50	57	49	52	51.6	16
Concord	42	57	44	55	56	60	48	51	51.7	18
Jersey	46	63	51	55	53	59	51	54	54.0	17
Pemberton	—	—	—	59	—	61	61	54	58.3	7
Pioneer	49	58	43	61	45	57	51	55	52.3	16
Rancocas	45	62	45	60	46	70	48	56	54.0	25
Rubel	50	57	52	56	58	61	53	55	54.0	11
Scammell	49	62	43	60	46	57	57	54	53.5	19
Stanley	—	—	—	—	—	64	53	55	57.1	11
Wareham	56	74	53	60	61	63	54	55	59.5	21

It will be noted that the difference between seasons was too variable for this time interval to be of any practical use. In only one variety (Pemberton) was the maximum difference less than 10 days. In this case it was 7 days, the usual time between pickings, which is still too much to make the lapsed time between full bloom and first picking of any use in estimating picking dates.

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[1] Contribution No. 615 of the Massachusetts Agricultural Experiment Station.

Because of the difficulty of fixing an exact date for full bloom and because the time of first picking is often influenced by considerations other than maturity of the berries, it was thought that the date the first flower opened and the date the first berry ripened would be more exact limits, would certainly be more easily determined, and might yield more consistent results. Therefore, during the years 1944, 1945 and 1946 five bushes of each variety were tagged and the dates of first bloom and first ripe berry recorded. Table II gives the results of this work.

TABLE II—DATES OF FIRST BLOOM AND FIRST FRUIT AND LAPSED TIME BETWEEN THE DATES

Variety	1944			1945			1946			Aver No. Days	Max Diff Between Seasons (Days)
	1st Bloom	1st Fruit	Days	1st Bloom	1st Fruit	Days	1st Bloom	1st Fruit	Days		
Adams	—	—	—	Apr 24	Jul 9	76	May 12	Jul 7	56	66	20
Atlantic	—	—	—	Apr 27	Jul 29	93	May 13	Jul 17	65	79	28
Burlington	—	—	—	May 7	Aug 2	87	May 19	Jul 18	60	73	27
Cabot	May 11	Jul 9	59	Apr 21	Jul 7	77	May 3	Jul 7	65	67	18
Concord	May 14	Jul 14	61	Apr 24	Jul 10	77	May 9	Jul 7	59	66	18
Dixi	May 18	Jul 18	61	May 5	Aug 1	88	May 20	Jul 18	59	69	29
Harding	—	—	—	Apr 23	Jul 26	94	May 9	Jul 8	60	77	34
Jersey	May 15	Jul 21	67	May 5	Aug 1	88	May 19	Jul 12	54	70	34
June	—	—	—	Apr 18	Jul 5	78	May 3	Jul 6	64	71	14
Pemberton	May 16	Jul 14	59	Apr 23	Jul 16	84	May 11	Jul 12	62	68	25
Pioneer	May 13	Jul 13	61	Apr 23	Jul 10	78	May 6	Jul 11	66	68	17
Rancocas	May 12	Jul 12	61	Apr 22	Jul 10	79	May 6	Jul 7	62	67	18
Rubel	May 14	Jul 15	62	Apr 27	Jul 18	82	May 13	Jul 13	61	68	11
Scammell	May 13	Jul 14	62	Apr 24	Jul 12	79	May 12	Jul 14	63	68	17
Stanley	May 14	Jul 11	58	Apr 22	Jul 11	80	May 11	Jul 7	57	65	23
Wareham	May 12	Jul 18	67	Apr 21	Jul 19	89	May 6	Jul 12	67	74	22
Weymouth	—	—	—	Apr 23	Jul 7	75	May 6	Jul 7	62	68	13

By comparing the maximum difference between seasons in Table I and Table II, it is readily seen that the variation for the period from first bloom to first ripe berry is greater than that for full bloom to first picking. The change in limits, therefore, has not been helpful from a practical standpoint.

DISCUSSION

Haller (4) and Haller and Magness (5) state that the time from full bloom to maturity is constant enough to be used for determining the picking date of apples. Ryall, Smith and Pentzer (6) make a similar statement for pears. On the other hand, Ellenwood (3) found that, for the 15 varieties on which he reported, the average variation in elapsed time was 20 days and his data show that it was as high as 36 days for Wealthy. Tukey (7) suggests that the lapsed time for early maturing varieties of fruits could be expected to be more variable than that for late maturing sorts since there is less time for the effect of short periods of unusual weather to be overcome. Since the blueberry belongs in the class of short season fruits, considerable variation would, therefore, be expected. The data presented show that there is a great deal of variation in the lapsed time, whether measured from full bloom to first picking or from first open blossom to first ripe berry.

Haller and Magness (5) found for apples no influence of temperature during the growing season on the elapsed time from full bloom to maturity but suggest that it may be a factor with other fruits. Ellenwood points out that temperature, sunshine and rainfall all influence growth and that high temperature at certain stages, such as the pink stage, may have more effect than at other stages. Temperature certainly influences the lapsed time in the blueberry and sunshine probably does. As shown in Table II, the elapsed time in 1945 was unusually long, bloom was early and picking was late. Early bloom was caused by an unusually warm April. During the week from April 8 to 14 the temperature each day went above 70 degrees F and on 4 days above 80 degrees F, the highest being 86 degrees F. Also, during April the number of hours of bright sunshine was 10 per cent above normal. May was cool and rainy with sunshine almost 14 per cent below normal. Early June was also cool, rainy and low in sunshine. As a result, the growth of blueberry fruits slowed almost to a standstill for 4 or 5 weeks. This delayed growth to such an extent that ripening of most varieties was later than normal in spite of the early bloom.

A survey of weather data does not suggest any correlation between air temperature and elapsed time. This is not surprising since it is plant temperature and not air temperature which determines growth rate. And since in bright sunshine leaf temperature (1, 2) may be 10 to 15 degrees above air temperature, it will probably be necessary to collect much data on plant temperature under field conditions before the exact relationship between temperature and growth can be obtained. Furthermore, no high correlation between bright sunshine and elapsed time is evident. Nor is this surprising, because periods of excessive sunshine are often accompanied by drought which slows growth. The effects of the various weather factors need to be carefully differentiated before their relationships to growth and hence to elapsed time can be accurately known.

As far as the blueberry is concerned, the lapsed time, whether measured from full bloom to first picking, or from first open blossom to first ripe fruit, is too variable to be used for estimating picking dates, and is influenced considerably by weather during the growing season.

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Highbush Blueberry Pollination Experiments

By E. M. MEADER and GEORGE M. DARROW, *U. S. Department of Agriculture, Beltsville, Md.*

THE question of the value of cross-pollination for the highbush blueberry varieties is still not fully settled. Growers in Michigan have planted solid blocks of the variety Rubel and have obtained large crops of berries. However, the early experiments of Coville (3) led him to state that "when blueberry flowers are pollinated with pollen from their own bush the berries are fewer, smaller, and later in maturing than when pollen comes from another bush (from a bush of another variety"). Experiments in North Carolina (5), New Jersey (6), and Massachusetts (1) have, in general, confirmed Coville's results. Experiments on the rabbiteye blueberry varieties already reported (4) indicate that this species of blueberry requires cross-pollination to obtain satisfactory crops.

The experiments described herein furnish additional information on the pollination requirements of the highbush blueberry. Because the blueberry produces a large number of flowers and fruits on a small plant, potted blueberry plants that can be readily moved about make excellent test material for studying the effect of environmental factors on pollination and fruit development.

In January of 1943, 1944, and 1945 potted plants were placed in a warm greenhouse to bring them into flower. In the 1943 experiments racemes or clusters of flowers were paired according to the number of flowers and their stage of development as well as to position on the plant, the method being similar to that described by Morrow (5). All flowers of each raceme were pollinated. In 1943 some pollinations were made in the field as well as in the greenhouse. In the 1944 and 1945 tests, when the maximum number of flowers were open and while those that had opened first still held their corollas, individual racemes or clusters were paired as to the number of open flowers, similar position on the plant, and size of the shoot producing the flowers. All open flowers on one raceme or cluster of the pair were self-pollinated, and those on the other were cross-pollinated; or, in some cases, the flowers on both paired racemes were selfed and then in addition those on one raceme were also crossed. This was considered the equivalent of an application of mixed pollen such as often happens when an insect visits blueberry flowers in a field planting of several varieties.

In 1944 and 1945, immediately after pollination had been completed, some bushes were placed in a warm greenhouse for 4 days and comparable bushes in a cold greenhouse for the same length of time. A high relative humidity was maintained during the flowering period. After different temperature treatments had been completed, all bushes were placed in one greenhouse and kept there till the berries had ripened. Ripe berries were harvested every other day as far as possible.

1943 EXPERIMENTS

In 1943, 14 varieties were self- and cross-pollinated, a total of 2,718 flowers being selfed and 3,401 being cross-pollinated. Where more than one variety of pollen was used in cross-pollination for comparison with selfing, the results were as if a single variety had been used. An illustration may be seen in the case of the variety Cabot in Table I. No difference in the effect of different varieties of pollen was noted.

In the greenhouse the average set for all varieties was 16 percentage points greater for the cross-pollinated flowers. Three varieties, Dixi, Harding, and Wareham, set much better and two, Weymouth and F–72, somewhat better when cross-pollinated, while five varieties (Cabot, Jersey, June, Rancocas, and Stanley) set little or no better when crossed than when self-pollinated. In the field no variety tested set better when cross-pollinated by hand, but open pollination, that is, by insects, gave the best set of all.

In the field cross-pollinated Jersey averaged 23 per cent larger than the selfed, but Rubel, Scammell, and Weymouth did not show much difference.

In the greenhouse all varieties ripened earlier when cross-pollinated than when selfed — from Cabot 2.5 days earlier to Wareham 13.2 days earlier. In the field Jersey averaged 5.0 days, Rubel 5.1, Scammell 1.6, and Weymouth 0.9 days earlier for the crossed as compared to the selfed berries.

All varieties that bore much larger berries when cross-pollinated also had a much greater seed content. Thus, Cabot, which averaged only 8 per cent larger berry, had 129 per cent greater seed content, whereas June and Stanley had 25 and 12 per cent greater seed content, respectively.

1943 EXPERIMENTS WITH JERSEY

A special study (Table II) was made of pollination of the Jersey variety. The crossed berries were earlier, but fewer flowers set; however the crossed berries weighed more, so that the total yield was 10 per cent greater than for self-pollination. The crossed berries had more seed, and more berries ripened the first week. On two bushes racemes were paired in quadruplicate as follows: one raceme was crossed with Scammell pollen, a second was selfed, a third was selfed and then pollen of Scammell was also applied, and a fourth was selfed and then a small amount of Rootone was applied to the pistils. In the comparison of the "selfed plus crossed" (x Scammell) with the "crossed" berries, the total yield was 48 per cent greater than in the case of the flowers that were crossed only. In the comparison of the "selfed plus Rootone" with the "selfed", the yield was 34 per cent greater than for the selfed. In a comparison of the crossed with the "selfed plus Rootone" the crossed had a 4 per cent less crop. In a comparison of the "selfed plus crossed" and "selfed plus Rootone" the "selfed plus crossed" had a 42 per cent greater yield.

Though Rootone as a supplement to pollination affected the set and the berry weight favorably, it did not have so much effect as did selfing

TABLE I—EFFECT OF SELF- AND CROSS-POLLINATION OF BLUEBERRY VARIETIES ON BERRY SET, DAYS TO MATURITY, BERRY WEIGHT, AND SEED CONTENT (1943)

Variety	Number of Flowers	Per Cent Set	Weighted Mean Days to Maturity	Number Berries Weighed	Mean Weight		Per Cent Increase Over Selfing	
					Berry (Cg)	Seed Per Berry (Mg)	Berry Weight	Seed Weight
A—Plants in Greenhouse								
Cabot ×self	111	95.5	58.1	106	0.99	8.6	—	—
Cabot ×Pemberton, Rubel, Stanley, Taylor, and Weymouth	208	90.4	55.6	208	1.07	19.7	8	129
Dixi ×self	100	26.0	67.5	24	1.39	9.9	—	—
Dixi ×Atlantic	100	83.0*	63.1	80	1.92	25.8	38	161
F-72 (Wareham ×Pioneer) ×self	71	64.8	73.0	46	1.27	7.7	—	—
F-72 ×Pemberton	59	84.7*	65.2	49	2.10	19.8	66	157
Harding ×self	100	6.0	63.2	6	0.44	6.9	—	—
Harding ×Dixi	100	66.0*	62.0	64	1.15	21.1	160	206
Jersey ×self	68	67.6	71.3	46	0.70 ±0.05	8.8	—	—
Jersey ×Rubel	68	73,5	67.7	50	0.99 ±0.12**	15.8	40	80
June ×self	111	73.9	60.4	70	0.89	9.5	—	—
June ×Weymouth	112	72.3	56.9	82	0.91	11.9	2	25
Kahler ×self	43	46.5	—	—	—	—	—	—
Kahler ×F-72	43	60.4	—	—	—	—	—	—
Orvis Williams ×self	37	91.9	65.3	34	0.99	13.3	—	—
Orvis Williams ×Weymouth	37	89.2	60.5	33	0.98	19.8	1	49
Rancocas ×self	26	96.2	58.7	25	1.01	18.0	—	—
Rancocas ×Weymouth	26	92.3	56.1	24	1.21	25.1	20	39
Stanley ×self	208	86.1	61.1	169	1.09	17.8	—	—
Stanley ×Weymouth	220	85.9	53.7	173	1.26	20.0	16	12
Wareham ×self	174	46.6	82.5	79	0.73	7.7	—	—
Wareham ×Weymouth	174	81.6*	69.3	142	1.07	21.7	47	182
Weymouth ×self	587	60.8	61.5	357	0.94 ±0.07	11.8 ±1.7	—	—
Weymouth ×*V. amoenum*, Minn. No 1 Taylor, Wareham, Cabot, June, and A-91	1,148	75.7*	57.7	869	1.14 ±0.03**	17.7 ±0.8†	22	45
Total Selfed	1,636	63.5						
Total Crossed	2,295	79.6*						
B—Plants in Field								
Jersey ×self	508	66.1	62.7	345	1.04 ±0.06	14.0	—	—
Jersey ×Scammell	522	56.7	57.7	293	1.28 ±0.05†	21.0	23	50
Jersey, open pollination	260	67.0	49.7	174	0.97	24.9	—	—
Rubel ×self	149	59.1	60.1	88	0.96	17.8	—	—
Rubel ×Jersey	150	40.7*	55.0	59	0.96	17.1	0	4
Rubel, open polliantion	244	81.6	62.1	70	0.76	16.8	—	—
Scammell ×self	319	60.5	59.4	184	1.02 ±0.06	16.7	—	—
Scammell ×Jersey	331	49.8*	57.8	148	1.08 ±0.08	19.6	6	17
Stanley, open pollination	188	64.4	46.0	44	1.13	22.6	—	—
Weymouth ×self	106	31.1	47.7	31	1.09	9.3	—	—
Weymouth ×Scammell	103	29.1	46.8	30	1.18	12.2	8	31
Weymouth, open pollination	202	43.6	42.7	60	1.16	—	—	—
Total selfed	1,082							
Total crossed	1,106							
Total open pollinated	894							

*P value in chi-square test less than 5 per cent point for the difference in a comparison with self-pollination.

**Using Student's t-test, the difference in a comparison with self-pollination is significant at the 5 per cent level.

†Also significant at 1 per cent level.

and crossing on earliness, set of fruit, size of berry, or seed weight. The "selfed plus crossed" gave 90 per cent more crop and the crossed 28 per cent more crop than the selfed.

TABLE II—EFFECT OF SELF- AND CROSS-POLLINATION AND THE ADDITION OF ROOTONE ON THE JERSEY BLUEBERRY VARIETY (THREE BUSHES IN THE FIELD, BELTSVILLE, MARYLAND, 1943)

Pollen Source	Mean Days to Maturity	Number Flowers	Number Berries	Per Cent Set	Chi-Square Value	Berry Weight (Gms)	Per Cent Increase	T Test	Seed Weight in Berry (Mgs)	Per Cent Seed in Berry	Per Cent Ripening—1 to 6 Weeks					
											1st	2nd	3rd	4th	5th	6th
Scammell	57.7	508	293	57	7.7	1.28 ± .05	23	1%	21	1.6	36	27	26	7	3	1
Self	62.7	522	345	66	—	1.04 ± .06	—	—	14	1.4	10	34	29	16	7	4
Scammell*	57.4	165	—	49	0.68	1.11 ± .06	25	5%	19	1.0	—	—	—	—	—	—
Self.	67.0	177	—	45	—	0.89 ± .07	—	—	11	—	—	—	—	—	—	—
Scammell + self	55.2	158	—	8	18.02	1.25 ± .09	41	1%	18	—	—	—	—	—	—	—
Selfed + Rootone	68.4	167	—	1	8.65	0.97 ± .10	9	—	12	—	—	—	—	—	—	—

*Paired with flowers recorded in the three entries below.

That natural hormones produced within the plant parts are responsible for the stimulation observed when cross-pollination occurred seems probable, since added synthetic hormone gave a fruiting response beyond that of self-pollination alone. This effect was apparent without appreciable change in the seed content of the berries that resulted from selfing plus hormone over those that were selfed only. The hormones resulting from cross-pollination stimulated earlier ripening and probably larger size than the hormones resulting from self-pollination, but the addition of self pollen to the cross pollen increased the set and size of fruit, and thus the total yield over the cross-pollinated by 48 per cent.

STANLEY POLLINATION — 1943

To determine the reason for the ripening of berries of a single variety over a period of several weeks, all 16 flowers of a single cluster were pollinated on February 26. The date of ripening of each berry was recorded. The resulting berries ripened over a period of 2 weeks, the first in 45 days from pollination, the last 59 days after pollination.

In a test to determine the effect of cross- and of self-pollination on the number of fully developed seed, the seed content of Stanley berries on a single bush was determined as follows: 62 crossed berries ripened in 54 days, averaged 1.32 gram weight, and had 33 (47 per cent) good seed; 63 selfed berries ripened in 61 days, averaged 1.04 gram weight, and had 14 (22 per cent) good seed. More than twice as many good seed were in the crossed berries, which weighed 27 per cent more per berry and ripened 7 days earlier than did the selfed berries.

CABOT POLLINATION — 1943

To determine the sequence of ripening, each flower of a raceme was pollinated in the greenhouse as it opened and the date of ripening and the seed development recorded. As will be noted in Table III, berries from the first two flowers to open did not mature at the same time, and one matured as much as 6 days later than a flower pollinated 2 days

TABLE III—RELATION OF TIME OF POLLINATION OF CABOT FLOWERS IN ONE CLUSTER TO TIME OF RIPENING OF THE BERRIES (1943)

Date Opening and Pollinated	Date Ripe	Days to Maturity	Berry Weight (Gm.)	Number of Seed Per Berry	
				Large	Total
Feb 13	Apr 5	51	1.31	35	91
Feb 13	Mar 29	44	2.09	68	87
Feb 15	Apr 5	49	1.18	25	78
Feb 15	Mar 31	44	2.04	65	82
Feb 15	Apr 5	49	1.17	32	75
Feb 15	Apr 6	50	1.22	30	78
Feb 15	Apr 7	51	0.89	12	85
Feb 17	Apr 7	49	1.09	33	73

later. The two earliest-ripening berries contained by far the most large seed (68 and 65) and were much larger than those ripening more slowly.

1944 POLLINATION EXPERIMENTS

Although the greenhouse pollinations in 1944 were more extensive than in 1943, because of loss of some plants records were obtained on only 3,758 pollinations on 13 plants. Besides comparing paired branches, the plants were also paired and half the plants were placed in a cool house for 3 to 4 days after pollination, the remainder being left in the warm, moist greenhouse. The records are given in Table IV.

TABLE IV—EFFECT OF COOL AND WARM TEMPERATURES FOR THREE TO FOUR DAYS AFTER POLLINATION ON CROSS- AND SELF-POLLINATED BLUEBERRIES IN THE GREENHOUSE (1944)

Variety	Greenhouse Temperature After Pollination	Number of Flowers	Per Cent Set	Days to Maturity	Average Berry Weight (Gm)
Rancocas, crossed	Warm, 68 degrees F	61	25	53.2	0.57
Rancocas, selfed	Warm, 68 degrees F	61	0	0	—
Rancocas, crossed	Cool, 59 degrees F	67	45	45.6	0.74
Rancocas, selfed	Cool, 59 degrees F	67	19	51.7	—
Rancocas, crossed	Warm, ———	49	36	—	0.79
Rancocas, selfed	Warm, ———	113	25	—	0.77
Concord, crossed	Warm, 68 degrees F	561	20	—	—
Concord, selfed	Warm, 68 degrees F	561	3	—	—
Concord, crossed	Cool, 43 degrees F	681	25	—	—
Concord, selfed	Cool, 43 degrees F	681	5	—	—
Stanley, crossed	Warm, 72 degrees F	158	49	47.4	0.69
Stanley, selfed	Warm, 72 degrees F	158	22	59.2	0.38
Stanley, crossed	Cool, 35 degrees F	220	66	56.8	1.30
Stanley, selfed	Cool, 35 degrees F	220	33	68.6	0.61

For these plants of three varieties, though the percentage of flowers set was low in general, the cross-pollinated flowers set much better than did the self-pollinated ones. Concord set little fruit when self-pollinated. Selfed Rancocas and Stanley set better than did selfed Concord, but less than half as well as when cross-pollinated. For the second lot of crossed versus selfed Rancocas in the warm greenhouse, the crossed berries were only slightly larger than the selfed ones. For the Stanley, however, the crossed berries averaged 82 per cent and 112 per cent larger than selfed for the warm and cool exposures, respectively. The crossed Rancocas (cool exposure) ripened 6 days earlier than the selfed, and the crossed Stanley (both exposures) ripened about 12 days earlier than the selfed Stanley.

Thus, on plants placed in a very cool greenhouse for 3 to 4 days just after pollination, the set was somewhat better than on plants kept in the warm house, and for the Stanley the size of the crossed berries was about twice that of the selfed berries.

1945 Pollination Experiments with Rubel

Two lots of potted plants of the Rubel variety, brought into the greenhouse in January, were used for pollination tests. Temperatures in this greenhouse were kept at about 60 degrees F at night and 65 to 75 degrees F during the day. Twelve plants of the first lot were pollinated March 2 and two more plants were pollinated March 3. The flower clusters on each plant were paired, one cluster of each pair being self-pollinated and the other cross-pollinated. The plants were also paired and seven were placed in a cold and seven in a warm greenhouse as soon as pollination had been completed. They remained 4 days at the different temperatures before being returned to a greenhouse averaging 65 degrees. The cold greenhouse ranged from 36 to 50 degrees, averaging 44 degrees. The warm greenhouse ranged from 65 to 82 degrees, averaging 72 degrees, or 28 degrees higher than the cold house.

A second lot of 24 plants was pollinated March 7 and half of them placed in the cool house for 4 days and half in the warm house. The temperature in the cold house ranged from 36 to 53 degrees F, averaging 44 degrees, and in the warm house it ranged from 62 to 80 degrees, averaging 71 degrees, or 27 degrees higher.

Fruit Set

For the entire 38 plants, 2,970 flowers were pollinated, half being cross- and half self-pollinated. Fifty-three per cent of the cross-pollinated and 41 per cent of the self-pollinated set. Thus, the cross-pollinated flowers bore 29 per cent more berries than the self-pollinated ones. The set was better for both the self- and cross-pollinated flowers at the lower temperature, averaging 35 per cent set for the warm and 59 per cent for the cold house. However, this difference was chiefly due to five plants that set few berries, or almost none, in the warm house, while all plants in the cold house had a good set.

Time of Ripening

The cross-pollinated berries ripened earlier than did the self-pollinated ones (Table V). During the first 8 days of the period within which the berries ripened 36 per cent of the self-pollinated, and 82 per cent of the cross-pollinated ripened. However, because of the poorer set the actual yield of the self-pollinated for the first 8 days of harvest was only 28 per cent of the total yield of the cross-pollinated.

The berries from each of 18 bushes were weighed (Table VI). The cross-pollinated berries averaged 0.93 grams each, while the self-pollinated averaged 0.84 grams, or 10 per cent less than the cross-

TABLE V—EFFECT OF SELF- AND CROSS-POLLINATION OF RUBEL BLUEBERRY ON EARLINESS OF RIPENING (1945)

Number of Bushes	Greenhouse Temperature for 4 Days	Pollen Used	Number of Berries Ripe				Per Cent Ripe First 4 Pickings
			First Picking	First 2 Pickings	First 3 Pickings	First 4 Pickings	
7	Warm, 72 degrees	Self	1	3*	7	13	19
		NJ-17-19	10	21*	33	40	55
7	Cold, 44 degrees	Self	1	11**	31	60	21
		NJ-17-19	42	99**	157	188	57
12	Warm, 71 degrees	Self	11	23†	40	68	42
		Rancocas	43	78†	119	144	77
12	Cold, 44 degrees	Self	4	14‡	49	82	50
		Rancocas	44	96‡	152	178	95
						All selfed	33
						All crossed	71

*Second picking 2.6 days after first, third 5.0 days after first, fourth 7.1 days after first.
**Second picking 2.3 days after first, third 5.3 days after first, fourth 7.9 days after first.
†Second picking 2.6 days after first, third 5.4 days after first, fourth 8.5 days after first.
‡Second picking 2.8 days after first, third 5.6 days after first, fourth 8.5 days after first.

TABLE VI—EFFECT OF HIGH AND LOW TEMPERATURE ON SELFED AND CROSSED RUBEL BLUEBERRIES (1945)

Berries	Cross-Pollinated		Self-Pollinated	
	Tempertaure		Temperature	
	Low	High	Low	High
Number	543.0	280.0	403.0	213.0
Average weight (grams)	0.97	0.87	0.84	0.83
Average seed weight (mg)	23.3	19.6	15.6	14.7

pollinated. The cross-pollinated berries from the plants placed in the warm house averaged 0.87 grams and those from plants placed in the cold house 0.97 grams, or 10 per cent more for the cold-house plants.

All the seed was extracted and weighed. That from the self-pollinated averaged 15.3 milligrams per berry and from the cross-pollinated 22.0 milligrams, or 44 per cent more. The good seeds in the berries of the 28 plants in the first lot were counted. The self-pollinated had 4,370 and the cross-pollinated 12,096, or an average of 14 good seeds for the selfed and 30 for the crossed berries. Berries from plants in the cold house had 41 per cent greater total seed weight than those from the warm house.

DISCUSSION

The highbush blueberry is dependent upon insects for pollination and set of fruit. Though, under favorable conditions in a greenhouse, the set following self-pollination may be as good as from cross-pollination, similar results may not prevail in the field, especially in seasons with unfavorable weather. Bees and other insects are not active at low temperatures or during inclement weather. When satisfactory pollinating weather is limited, the need for and benefits from cross-pollination may be correspondingly great. When the pollinating season is favorable, self-pollination for some varieties may result in as good a set as from cross-pollination. Relatively low temperature following pollination seems to have a favorable effect on fruit set.

The final crop depends largely on the number of flowers setting fruit and on the size of the mature fruit. For most varieties cross-pollination increases the crop sufficiently to warrant the interplanting of two or more varieties. The increased crop beyond that resulting from self-pollination more often may be due to increased berry size than to a better set of fruit. The larger berries have more seeds, and more good seeds are found in cross-pollinated than in self-pollinated berries, under both greenhouse and field conditions.

The earlier ripening of cross-pollinated fruit and the later ripening of self-pollinated may often be important. Where early fruit is the most valuable, cross-pollination gives added advantage in the percentage of the crop harvested early; furthermore, the berries are larger than those resulting from self-pollination. For varieties like Cabot that have a long period of harvest, cross-pollination, by insuring early ripening and large berries, should be especially valuable. In contrast, in the North, where late-ripening fruit of late varieties, such as Rubel and Jersey, is the more valuable, self-pollination with its somewhat smaller but later ripening crop may be relatively more profitable.

SUMMARY

Three years of pollination experiments, using 15 highbush varieties, showed that cross-pollination usually increased the crop sufficiently to warrant inter-planting of two or more varieties, even though the set was not always greater. Cross-pollination tended to increase the percentage of fully developed seed per berry and resulted in larger berries than self-pollination. Cross-pollinated berries also matured earlier than the selfed ones. Selfed berries of the Jersey variety were stimulated beyond the response from selfing alone by applying a synthetic hormone to the pistils, but the response did not equal that from self-pollination plus cross-pollination. The addition of selfed pollen to crossed pollen resulted in an increased yield over crossed pollen alone. Low temperatures, but above freezing, for 4 days immediately following pollination was not detrimental to fruit set. Cross-pollination was relatively more effective at the low temperature than was self-pollination, and the mature cross-pollinated berries containing a high number of well-developed seeds tended to be larger than the self-pollinated berries.

In 1944 the set of Rancocas, Concord, and Stanley was much better for the crossed than for the selfed flowers. The selfed Concord did not set enough to give a commercial crop. For the Stanley, the weight of crossed berries was almost double that of selfed berries, and, because of the better set and size, the actual crop for the crossed was more than four times that of the selfed. The crossed Stanley flowers that were held 4 days after pollination in a cool house produced more than 2.5 times as much fruit as did those in the warm house, due to a better set and berries of about twice the size.

In 1945 the cross-pollinated Rubel gave a 43 per cent greater crop than the self-pollinated. The yield for the first 8 days of harvest was 3.6 times that of the self-pollinated.

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Cultivation of Low-Bush Blueberries

By F. B. Chandler, *Massachusetts Agricultural Experiment Station, Cranberry Station, East Wareham, Mass.*

In 1940 an experiment was started at the Maine Agricultural Experiment Station to determine the best method of cultivating the low-bush blueberry. This study was made principally to determine the rate of spread and number of aerial branches or stems of eight different selections of blueberries grown with different amounts of organic matter in the soil and burned (pruned) at different times.

Methods

Several years previous to starting the experiment half of the area was planted to a fertilized (500 pounds/acre or more) crop, usually buckwheat, which was incorporated with the soil annually. The other half was kept fallow. The treatments were planned so that the factorial design of experiment could be used. One inch of peat was mixed with the top 6 inches of soil for some of the plots. Fertilizer was applied 6 inches below the surface of the soil to all plots, half received 4–8–8 at the rate of 1000 pounds per acre and half received 0–8–8 (4–0–0 was applied in 1941). Sods about 6 inches square of eight selections were set in the spring of 1940 and burned after setting. One third of the plants were burned again in the spring of 1941 and fall of 1942 (a burn in the fall of 1942 has the same effect on the plant as a burn in the spring of 1943). One third of the plants were burned in the fall of 1942. The other third was not burned. The original plan called for burning in the fall of 1943 but conditions did not permit this. The selections were planted 4 feet apart. The plant spread was determined in the fall of 1940, 1941, 1942 and 1945 by a 4 foot quadrat divided into 100 squares. The number of branches originating from below ground, "stems", were counted in the fall of 1940, 1941 and 1942. The data were analyzed by the analysis of variance.

Results

The use of both buckwheat and peat increased the number of stems and the use of peat alone increased the spread of blueberry plants. Buckwheat and peat together gave better results than either one alone, see Table I. Frequent burning decreases the number of stems and the spread of plants. The detrimental effect of frequent burning was evident in 1945 (Table II) when the plant spread was less on the plots burned twice than on those burned only once and was least on the plots burned three times (1). Table III shows that three of the selections (2811A, 2827A, and 3313A) did not have the spread significantly decreased by frequent burning.

In selecting blueberry plants for breeding or to establish a cultivated blueberry industry the plant should be affected as little as possible by burning. A selection should also be a good spreading plant with many stems, such as 3208A, 3303A, 3310A, 3313A and 3312A, Tables I and IV.

TABLE I—NUMBER OF STEMS AND NUMBER OF SPACES OCCUPIED BY BLUEBERRY PLANTS WITH DIFFERENT TREATMENTS

Treatment	Number of Stems		Number of Spaces	
	Number	Dif Nec	Number	Dif Nec
	Culture			
Buckwheat	101	3.9	12.3	
Clean culture	95		11.7	
	Burns			
1940, 1941 and 1942	80	4.7	10.8	1.0
1940 and 1942	103		12.1	1.3*
1940	112		13.2	
	Peat			
Peat	102	3.9	12.6	0.8
No peat	94		11.5	1.0*
	Selection			
2811A	78	7.7	10.8	1.6
2827A	97		10.5	2.1*
3208A	97		11.7	
3303A	108		13.1	
3310A	89		13.0	
3313A	99		11.6	
2822A	72		10.1	
3312A	147		15.6	
	Culture × Peat			
Buckwheat and peat	110	5.5	13.3	1.1
Buckwheat and no peat	92		11.3	
Clean culture and peat	95		11.8	
Clean culture and no peat	96		11.7	

*Difference necessary for significance at the 1 per cent level.

TABLE II—NUMBER OF SPACES OCCUPIED BY BLUEBERRY PLANTS IN DIFFERENT YEARS WITH DIFFERENT BURNING TREATMENTS

Year of Measurement	Years Burned		
	1940, 1941, 1942	1940, 1942	1940
1940	4.4	4.7	5.1
1941	4.8	5.9	6.3
1942	10.2	11.5	12.4
1945	24.0	26.4	29.0

Difference necessary for significance between burns 1.9 at 5 per cent and 2.5 at 1 per cent.

TABLE III—NUMBER OF SPACES OCCUPIED BY EIGHT SELECTIONS OF BLUEBERRY PLANTS WITH DIFFERENT BURNING TREATMENTS

Selection	Years Burned		
	1940, 1941, 1942	1940, 1942	1940
2811A	10.2	10.3	11.9
2827A	10.2	10.0	11.2
3208A	9.7	12.8	12.5
3303A	11.5	12.6	15.2
3310A	11.4	12.4	15.3
3313A	12.8	11.0	10.8
2822A	9.0	9.5	11.9
3312A	11.9	18.3	16.6

Difference necessary for significance between burns 2.7 at 5 per cent and 3.6 at 1 per cent.

TABLE IV—NUMBER OF SPACES OCCUPIED BY DIFFERENT SELECTIONS OF BLUEBERRY PLANTS IN DIFFERENT YEARS AND THE PERCENTAGE INCREASE OF SPACE OCCUPIED FROM 1940 TO 1945

Selection	Years				Per Cent Increase 1940 to 1945
	1940	1941	1942	1945	
2811A	4.2	4.4	9.4	25.1	597
2827A	4.5	5.1	9.2	23.0	511
3208A	4.4	5.7	11.0	25.5	580
3303A	4.4	6.1	13.3	28.6	650
3310A	4.2	5.3	10.9	31.6	752
3313A	4.3	5.9	11.7	24.2	463
2822A	3.9	4.5	10.3	21.8	459
3312A	8.0	8.3	14.9	31.1	290

Difference necessary for significance 3.1 at 5 per cent and 4.1 at 1 per cent.

APPLICATION

The areas which are not covered with blueberry plants from natural plantings and which can be cultivated should be plowed and planted to buckwheat. This will smother out the weeds, supply feed for bees and produce organic matter for the soil. After several crops of buckwheat have been incorporated into the soil 1 inch of peat should be cultivated into the soil. Peat may be obtained at a reasonable cost from companies making a business of mining it. For economy the peat should be purchased unbaled and with considerable moisture. In sections where there is not peat industry, growers may dig their own peat from near-by bogs in the fall for use the following spring. Sods of blueberry plants about 6 inches square should be set in the spring in rows 2 feet apart and 2 feet between rows. If plants are propagated as suggested by Hildreth (2) they should be set 6 to 12 inches apart in rows 1 foot apart. The ground will be covered in about 5 years by following either of these methods of transplanting.

SUMMARY

The low-bush blueberry may be cultivated by incorporating cover crops and peat in the soil. The plants should be burned when set and not oftener than every 3 years thereafter for the best spread of plants. Selections to be used for cultivation should spread well, produce a large number of stems and be affected as little as possible by burning, in addition to having good fruit characters.

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Influence of Fineness of Shredding on Value of Sphagnum as a Medium for Transplanted Blueberry Seedlings[1]

By W. H. Childs, *West Virginia Agriculture Experiment Station, Morgantown, W. Va.*

In a recent paper (1) the author reported obtaining considerably better growth of blueberry seedlings when grown in sphagnum shredded through a screen with 4 meshes to the inch than when grown in the conventional peat-sand medium. Stoutemyer, and his associate (2, 3, 4) recommended sphagnum shredded by rubbing it through a screen having 3 or 4 meshes to the inch, or by use of a 1-inch diamond screen in a hammer mill. Since no 1-inch diamond screen was available, a little sphagnum was run through a hammer mill using a slightly smaller round screen while seeking a rapid method of shredding. This pulverized the sphagnum to such an extent, however, that mortality of the seedlings was high, and growth of those that lived was very poor. About 300 seedlings also were grown in sphagnum rubbed through a half-inch mesh screen. These seemed to do as well as those reported on in the previous paper.

These observations raised the question as to whether there would be a progressive decrease in the amount of growth made by blueberry seedlings as the fineness of shredding was increased or whether there would be a considerable range within which growth would vary little. A series of treatments was set up to study this, and also to compare the growth obtained with that made in peat.

Materials and Methods

Dried commercial sphagnum was shredded by rubbing it through screens of 2, 3, 4, 6, and, in one case, 16 meshes to the inch. Some also was broken up by hand. Peat of pH 3.5 was used as it came from the bale, excepting that sticks were picked out.

The plants were grown in the greenhouse in 2½ by 2½ by 3 inch wooden bands. Fifteen bands formed a row across the greenhouse bench, and this was used as the experimental unit with the first and fifteenth bands omitted when measuring, to eliminate as much as possible of the border effect. The layout was systematic, with the treatments for each cross in the following order: hand-shredded, 2-mesh, 3-mesh, 4-mesh, 6-mesh, 16-mesh, and peat. There were three replications of one cross, and one of each of the other seven, giving a total of 150 seedlings transplanted into each medium, with the exception of the 16-mesh sphagnum.

The sphagnum or peat was moistened and pressed firmly into the bands. The seedlings used were from cross-pollinations made in the spring of 1944. The seeds were germinated on peat moss during the fall and early winter of 1944, and the seedlings were held in peat in a state of partially suspended activity for a year by keeping them in a crowded condition in the pans and applying no nutrients. Growth was

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[1] Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 365.

less than an inch in practically all cases before they were pricked off in late February, 1946. They were subjected to identical greenhouse conditions during the experiment. A nutrient solution, made by adding 1 pound of 5–10–5 fertilizer to 10 gallons of water, was applied to all plants at 3-week intervals. A few seedlings died shortly after transplanting, as indicated in Table I. The seedlings were grown in the greenhouse until September, 1946, when they were moved to the cold frame. Measurements of linear growth were made at that time.

TABLE I—Average Inches of Growth Made by Blueberry Seedlings in Sphagnum Shredded to Several Degrees of Fineness, and in Peat

Cross*	Hand-Shredded	2-Mesh	3-Mesh	4-Mesh	6-Mesh	16-Mesh	Peat
Jersey ×Atlantic	73.4	77.8	80.0	69.0	81.5	61.2	67.6
Rubel ×4	76.3	72.7	96.4	83.8	68.1	——	61.5
Jersey ×Rancocas	72.9	85.1	82.8	73.7	97.3	——	78.6
Rubel ×Dixi	70.7	82.6	75.7	72.5	78.9	——	87.1
Pioneer ×4	67.4	123.6	90.3	105.0	101.5	——	70.1
Concord ×4	93.8	84.8	92.2	79.4	83.8	——	57.6
Atlantic ×Stanley	96.0	78.0	88.2	74.7	87.9	——	63.1
Jersey ×Dixi	82.6	69.8	72.6	83.7	80.5	——	73.1
Entire group**	77.7	82.5	83.6	77.6	84.8	61.2	70.3
Total number of seedlings	121	121	119	119	111	11	107
Per cent mortality	6.9	6.9	8.5	8.5	14.6	15.4	17.7

*The numbered parents are low bush plants in the West Virginia selection planting.
**The figures given for the entire group are averages derived from the original data.

Results

The results obtained are summarized in Table I. In analyzing the results it should be realized that the growth made by a group of hybrid blueberry seedlings will vary considerably under identical growing conditions, and it is not to be expected that differences will be clear-cut.

It is apparent that there was no significant difference in growth between the five major treatments using sphagnum. The small differences shown in the average of all crosses are nullified by the variations found within the various crosses. There are indications that the 16-mesh shredding was too fine for best growth, but the number of individuals involved was too small to draw definite conclusions. Peat apparently was not quite as good a medium as sphagnum since not only was average growth for the whole group lowest, but this was true for four of the eight crosses, and the treatment was next to the poorest for two more of the crosses. In addition mortality was highest in peat and watering was slightly more difficult since it washes to some extent. Mortality increased somewhat with increased fineness of shredding of the sphagnum, but the differences would not be significant for the four coarser shreddings.

From the practical viewpoint, a blueberry hybridizer who did not have a suitable hammer mill available could pull his sphagnum apart by hand or rub it through a 2-mesh screen, rather than take the time to rub it through a finer screen. Shredding through a 2-mesh screen takes a little longer than hand-shredding, but gives a product with which it is easier to work.

SUMMARY

Nine hundred and fifteen blueberry seedlings representing eight crosses were grown in wooden bands in the greenhouse at Morgantown, West Virginia, from February to September, 1946, to study the effect of fineness of shredding sphagnum on the linear growth made. The treatments involved were hand-shredding, and shredding through screens having 2, 3, 4, 6, and 16 meshes to the inch. In addition there was one treatment using peat. All plants received identical greenhouse care, including applications of nutrient solution at 3-week intervals. Fineness of shredding made no significant difference in the amount of linear growth obtained, but there were indications that the 16-mesh treatment was somewhat poorer than the others. Peat was slightly less satisfactory than all but the 16-mesh sphagnum treatment both in the amount of growth made and in the per cent mortality of the seedlings.

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Influence of Several Soil Management Practices Upon the Yield of Cultivated Blueberries[1]

By E. P. CHRISTOPHER and V. SHUTAK, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

THE cultivated blueberry is of increasing interest to both commercial and amateur growers in Rhode Island. The information on cultural methods is limited and in some cases conflicting. Chandler and Mason (1) from Maine report increased growth when mulches are applied over clay loam soils, and decreased growth when they are applied over sandy soils. Savage and Darrow (2) report experiments in Georgia where, on sandy soil, growth was increased by all mulch treatments and was greatest under sawdust. Local growers have generally practiced clean cultivation. An experiment was started in 1942 at the Rhode Island Station to seek information under local conditions.

METHODS

In the spring of 1942 a practically level area on well-drained Narragansett loam soil was selected for the experiment. Two-year Pioneer blueberry plants were set 6 by 8 feet apart in plots so that there were 6 plants in each of 20 plots with buffer rows in each direction. While most of the buffer plants were Pioneer, a row each of Cabot and Rubel was interspersed to improve cross pollination conditions. Every effort was made to have all plants equally vigorous, and during the first season they were given uniform treatment, that is clean culture and a cover crop of buckwheat. In the spring of 1943, all plots received a complete fertilizer, 5–10–10, at the rate of 1,000 pounds per acre and differential treatments were begun as follows:

A. Clean culture with a cover crop of buckwheat about August 1.
B. Mulch of straw and hay.
C. Mulch of sawdust.
D. Clean culture.

During 1944 and 1945 the plots were occasionally weeded, and supplementary straw and sawdust were added. Before the 1946 season, complete fertilizer was applied as before and the bushes were pruned.

RESULTS

In 1945 a sizable crop was harvested from the plots and while the differences were not great, it appeared that the plants under sawdust were doing best. This trend became very pronounced in 1946, as will be noted from the yield data in Table I. The yield from plots receiving sawdust mulch was more than twice that from plots with clean culture or clean culture and cover crop, and far ahead of the yield from plots receiving straw. An observation on the labor required for weed control is interesting. Considerable quack grass made cultivation difficult and, because of poor control, this weed may have reduced the yield

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[1] Contribution No. 695 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

TABLE I—YIELD OF PIONEER BLUEBERRIES UNDER VARIOUS SOIL MANAGEMENT TREATMENTS (1946)

Treatment	Yield (Lbs.)
A. Clean culture and cover crop	89.3
B. Straw mulch	101.0
C. Sawdust mulch	192.8
D. Clean culture	76.8

Analysis of variance calculations shows sawdust mulch significantly superior to all other treatments at 1 per cent level; straw mulch significantly better than clean culture and clean culture and cover crop at the 1 per cent level.

from the clean culture plots to some extent. Under straw mulch, quack grass was much easier to control. The individual grass plants could be pulled out and additional mulch applied. With sawdust, the control was simplest since the stolons tended to develop in the mulch material and could be easily pulled out.

CONCLUSIONS

These preliminary data indicate that a sawdust mulch is superior to the other soil management systems studied and is worthy of general trial. Additional data will be collected to determine if there are any long-term injurious effects of sawdust.

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The Effect of Planting Treatment and Soil Management System on the Production of Cultivated Blueberries

By W. H. Griggs and H. A. Rollins, *University of Connecticut, Storrs, Conn.*

Although the commercial importance of the highbush blueberry (*Vaccinium corymbosum*, L.) is now appreciated, there has been very little published regarding practicable planting treatments and soil management systems for this domesticated plant. Coville (3), in discussing field planting in soils deficient in peat or peatlike matter, recommended setting the plants in a mixture of two to four parts peat or half-rotted oak leaves to one part of sand. Johnston (6) suggests mixing a shovel full of peat with the soil in each planting hole if the soil lacks organic matter. Kramer *et al.* (7) found that trenching mulching material, especially peat, alongside the root zones at planting time, greatly improved survival and yield. The older blueberry plantings have generally been clean cultivated, but recently some of the possibilities and effects of mulches have been considered. Clark (2) reported an increase in growth and yield by the application of hay mulch to blueberries on upland soils which had been under clean cultivation during their first four seasons. Kramer *et al.* (7) also obtained increased yields of both highbush and dryland blueberries with various mulch materials during their first and second growing seasons, but plant survival of the dryland blueberries was decreased. Chandler and Mason (1) found that mulches increased the retention of soil moisture, maintained a lower soil temperature, reduced the growth of blueberry plants in sandy soil, and increased their growth in clay loam. Savage and Darrow (9) obtained greater growth and survival of blueberries during the first three growing seasons from mulched plots than from plants under clean culture and concluded that sawdust was definitely superior to either oak leaves or rye straw.

Materials and Methods

This experiment was initiated at Storrs in the spring of 1941 by W. P. Judkins and H. A. Rollins for determining the most desirable planting treatment and soil management system for cultivated blueberries in Connecticut. Three horticultural varieties of blueberries, Jersey, Rubel, and Wareham, were selected for study. Thirty 3-year-old plants of each variety were set 5 feet by 10 feet apart in 18 plots. A single plot consisted of one row of five plants of one variety. Plants 1, 3 and 5 in each plot were set in soil mixed with ½ bushel of peat moss, while plants 2 and 4 received no peat moss at time of planting. Plants which died were replaced with younger plants of the same variety.

All plots were clean cultivated during the first growing season. In the fall of 1941, the plants were subjected to three systems of soil management; clean cultivation, sawdust mulch, and hay mulch; two plots of each variety receiving each treatment. The clean cultivation plots were shallow cultivated frequently until July and seeded with Rosen rye in early September. The sawdust mulch plots received about 5 inches of hardwood sawdust which had been weathered for 3 years, while the hay mulched plots received about 5 inches of hay. Additional mulch was added when needed to suppress the growth of grass and weeds. No fertilizer was applied in 1941, but beginning in 1942 each plant received 1 ounce of 5–10–5 commercial fertilizer, and the amount applied has been increased 1 ounce each year thereafter. The plants were moderately pruned each March.

The blueberry plots are situated on relatively high ground which 10 years before had been in woodland. The soil has been defined by Morgan (8) as of the Gloucester type and described as hill land of light to medium textured, moderately drained, glacial till soil. Soil samples were taken to a depth of 6 inches in November 1941 before fertilizer was applied and again in October 1946. In sampling the soil under the mulches all of the hay or sawdust was scraped away and excluded from the sample. The "rapid tests" of mineral nutrients and organic matter, as well as moisture determinations, were made under the supervision of A. V. King and R. I. Munsell of the University of Connecticut Agronomy department. In view of the number of plants which died and the relatively high pH values of the November 1941 soil samples (Table I), finely ground sulfur was added to each plot in April 1946. In field studies with highbush blueberries growing on soils of high pH (6.0), Harmer (5), had reported greatly increased growth, yield, and plant survival with heavy applications of sulfur (2 tons per acre). Sulfur was added in an amount sufficient to obtain an expected acidity of pH 4.5, as recommended by Darrow *et al.* (4).

Yield records were taken in 1944, 1945 and 1946. Measurements of linear shoot growth during the season of 1946 were recorded in October for each plant. The data used in this article were obtained from plants included in the original planting, excluding the replacements. The data were analyzed statistically under the direction of C. I. Bliss, Biometrical Consultant at the Storrs Agricultural Experiment Station.

RESULTS AND DISCUSSION

The soil tests in the first year of the experiment, and after 5 years of mulching, cultivation and fertilizer applications, are summarized in Table I. The soil acidity is expressed as pH, moisture as the moisture equivalent on a percentage basis, and organic matter as percentage loss on ignition, water free basis. The quantities of available nutrients were expressed in approximate pounds per acre. The values are the means for the six replicates of each type of soil management.

The lower pH values for the 1946 soil samples were undoubtedly due not to the mulch but to the sulfur applications. These were made in an attempt to stimulate more vigorous growth and prevent further plant loss. Kramer *et al.* (7) found that soil acidity of blueberry plots was little affected by mulches or fertilizers. According to Gourley (10), soil under fruit trees which had been mulched for 12 years with both hardwood and pine sawdust was little or no more acid (pH 5.07)

TABLE I—SOIL ACIDITY AND AVAILABLE PLANT NUTRIENTS, NOVEMBER 13, 1941, AND SOIL ACIDITY, SOIL MOISTURE, ORGANIC MATTER AND AVAILABLE PLANT NUTRIENTS AS AFFECTED BY SOIL MANAGEMENT AND FERTILIZATION, OCTOBER 15, 1946

(Means for Six Plots)

Soil Management	Sampling Date	pH	Approximate Pounds Per Acre									Organic Matter (Per Cent)	Moisture Equivalent (Per Cent)
			NO_3	NH_3	P	K	Ca	Mg	Mn	Al	Fe		
Cultivation	Nov 1941	5.7	9	10	40	310	560	75	—	—	—	—	—
	Oct 1946	4.9	26	125	160	280	460	55	37	250	33	0.62	18.60
Sawdust	Nov 1941	5.9	10	10	30	365	760	90	—	—	—	—	—
	Oct 1946	5.5	5	165	80	225	1360	75	8	215	26	0.61	19.28
Hay.....	Nov 1941	5.5	10	10	20	500	800	90	—	—	—	—	—
	Oct 1946	4.9	52	125	285	500	770	108	38	250	29	0.79	21.22
Differences required for significance													
5.0 per cent level												0.10	1.56
1.0 per cent level												0.14	2.19

than similar soil under either bluegrass sod (pH 5.22) or wheat straw (pH 5.35).

In regard to available nutrients, it is apparent from the soil analyses that all of the vital elements listed in Table I were present in sufficient quantities for vigorous plant growth, with the possible exception of nitrogen. The phosphorus content increased markedly after five years of fertilizer applications under all three soil management systems, while potassium and magnesium were little affected. There was a considerable increase in nitrate under clean cultivation and hay mulch while ammonium showed an increase under sawdust mulch as well. The reduction of nitrate content under sawdust mulch is consistent with Turk's evidence (11), which showed that sawdust decreased the accumulation of nitrates because of microbial assimilation.

The contents of manganese, aluminum, iron, organic matter and moisture are available for the 1946 soil samples only. The content of organic matter was significantly greater under the hay mulch plots than under either clean cultivation or sawdust. Moisture equivalent values were also significantly greater under the hay mulch plots. Although the differences in moisture retentiveness under the three types of soil management were statistically significant, they were unexpectedly small since Kramer *et al.* (7) found almost double the soil moisture under mulches as in cultivated blocks. Chandler and Mason (1) also reported significantly greater moisture retention from mulches as compared to clean cultivation. The similarity of the moisture equivalent values in the present experiment, may have been due partially to precautions taken to exclude all mulching material from the soil samples.

The mean yields per plant for 1944, 1945 and 1946, the linear shoot growth data for 1946, and the numbers of plants surviving to 1946 for each type of soil management and for each variety are shown in Table II. From 1944 to 1946, the average over-all yield increased from 2.62 to 15.89 pints. An analysis of the 1944 data showed no significant differences in yield associated with either variety or system of soil management. In 1945 there were still no significant differences in yield between varieties or systems of soil management. Sawdust, however, continued to give the highest mean yield, while in 1946 the plants under sawdust mulch yielded significantly more than those under the other types of soil management. Including all three varieties, plants mulched with sawdust averaged 20.75 pints per plant, whereas plants under clean cultivation and hay mulch averaged 14.07 and 12.85 pints per plant, respectively. In comparing variety yields for 1946 averaged over the three soil management systems, Rubel yielded significantly more per plant (20.33 pints) than either Jersey (13.92 pints) or Wareham (13.42 pints). Moreover, the yield of Rubel increased more with sawdust mulch than that of the other two varieties, the only significant interaction between soil management and variety.

In regard to facilitating such operations as pruning, harvesting and weed control, all persons involved considered sawdust mulch as more desirable than either clean cultivation or hay mulch.

TABLE II—Yields, Growth and Survival of Cultivated Blueberries as Affected by Soil Management

Treatment and Variety	Mean Yield Per Plant (Pints)			Mean Linear Shoot Growth Per Plant (Centimeters)	Number of Plants in 30 Surviving to 1946
	1944	1945	1946	1946	
Treatment					
Sawdust mulch	3.12*	8.74*	20.75*	16.75*	16
Hay mulch	1.73	8.65	12.85	12.99	19
Clean cultivation	3.00	6.62	14.07	13.90	25
Variety					
Rubel	3.19	7.00	20.33	15.42	23
Jersey	2.41	9.87	13.92	15.42	18
Wareham	2.25	7.14	13.42	12.80	19
General mean	2.62	8.00	15.89	14.55	20
Difference required for significance					
5.0 per cent level	—	—	5.57	2.20	—
1.0 per cent level	—	—	7.86	3.11	—

*Each value represents the plant average for six plots.

In 1946 the average growth in centimeters of the plants in each plot was correlated with the mean yield in pints for the same plants. The correlation coefficient of 0.64 between growth and yield was highly significant ($P<0.01$). The sawdust mulched plants made an average linear shoot growth of 16.75 centimeters which was significantly greater than the growth made by plants under either clean cultivation (13.90 centimeters) or hay mulch (12.99 centimeters). Both Rubel and Jersey made significantly greater shoot growth than Wareham.

It is interesting to note that previous workers (1, 7, 9) have obtained favorable increases from mulches during the first two or three growing seasons, while under the conditions of the present experiment no significant differences in yield were obtained until the sixth season after planting.

Setting the plants in soil mixed with ½ bushel of peat moss increased the 1944 mean yield by 1.58 ± 0.54 as computed from 17 paired comparisons within plots. In computing the mean difference, each difference was weighted by $\frac{N_1 N_2}{N_1 + N_2}$ to obtain a weighted mean difference in yield where N_1 and N_2 were the numbers of plants with peat and without peat. From the ratio of the mean difference to its standard error $t = 2.92$, a significant value ($P = 0.01$). Hence, during the first cropping year, the peat moss at planting increased yield independently of variety or soil management system. The effect disappeared in succeeding years, the difference and its standard error for 1945 being 0.98 ± 0.88, and for 1946 it was 0.07 ± 1.52. The peat moss did not affect plant survival. Of the 54 plants treated with peat moss 67 per cent survived, as compared with a 69 per cent survival of the 36 plants not treated with peat moss.

There were no significant differences in plant survival between the three varieties and under the various types of soil managment. Of the original 30 plants set in 1941, the numbers surviving by 1946 in each variety and under each system of soil management are shown in the last column of Table II. The fact that plant survival was least under sawdust mulch and highest under clean cultivation seems to accord with the results of Kramer *et al.* (7) who suggested that mulches should be withheld until the plants become well established under clean cultivation. In the present experiment the mulch was first applied approximately 6 months after the plants were set. The survival record suggests that an even longer interval may be desirable.

SUMMARY

Three horticultural varieties of highbush blueberries were set in the spring of 1941 on relatively high ground at Storrs, Connecticut. Plants 1, 3 and 5 in each plot were set in soil mixed with ½ bushel of peat moss while plants 2 and 4 received no peat moss. All plants were cultivated during their first growing season. Mulches were applied in the fall of 1941, and the plants were grown under either clean cultivation, sawdust mulch or hay mulch.

Data taken on soil conditions, yields for 1944, 1945 and 1946, plant survival and linear shoot growth in 1946 were analyzed statistically. After five years, the soil under hay mulch had the highest content of organic matter and the greatest moisture retentiveness. There were no significant differences in yields between the varieties or as a result of the various types of soil management until 1946. In comparison with either clean cultivation or hay mulch; sawdust mulch gave greater yields, longer shoot growth, and facilitated such operations as pruning, harvesting, and weed control. Rubel gave the highest yields, Wareham the smallest shoot growth; shoot growth and yield being positively correlated.

Treatment with peat moss at planting increased the yield in 1944, but had no subsequent effect. Plant survival was not affected by peat moss planting treatment or related to variety. Although the difference was not significant, more plants survived under clean cultivation than under either type of mulch, which suggests that mulch applications might be delayed for a longer period than was practiced in this experiment.

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Breeding Strawberries for Resistance to Red Stele Root Disease

By George F. Waldo and George M. Darrow, *U. S. Department of Agriculture, Beltsville, Md.,* W. F. Jeffers, *University of Maryland, College Park, Md.,* and J. B. Demaree and E. M. Meader, *U. S. Department of Agriculture, Beltsville, Md.*

Abstract

This paper will be published in full in the *Annual Report* of the *Peninsula Horticultural Society.*

This trouble was first recognized as a specific disease in 1931 in Scotland, where it has caused serious losses and where in most locations resistant varieties only are grown. In England, Ireland, and other parts of northern Europe it is also recognized as a serious disease. In Scotland, Miss Millen and later R. D. Reid bred varieties resistant to the disease, obtaining resistance from an obscure highly resistant variety known as "52", and recently from the American variety Aberdeen.

In America, Anderson, of Illinois, recognized the disease in 1930, and he and Colby found the Aberdeen to be highly resistant. Their tests and those of others indicated that most American varieties are very susceptible. Because of the extent and severity of the disease, breeding work to obtain resistant varieties was begun by the United States Department of Agriculture in 1937. The Aberdeen, three selections from Scotland, and some from Oregon have been used as resistant parents in crossing with many varieties and selections. Three methods of testing have been used: 1, Seedlings have been planted directly in red-stele-infested soil at Beltsville, Maryland, and in cooperation with the Maryland Agricultural Experiment Station near Pittsville, Maryland. The best uninfected seedlings were then retested. Some 38,000 seedlings were thus tested, the Temple variety was introduced, and many selections are still under test. One selection, U. S. 3205, is being propagated for introduction. 2, Seedlings have been grown in pots in the greenhouse and cultures of the disease fungus used in each pot. About 11,000 were so tested, and the uninfected seedlings were then planted in infested soil near Pittsville, Maryland. Selections from these seedlings are still being tested.

Because less than half the seedlings were infected in the greenhouse and yet most of the rest later became infected, a third method was tried. 3, Since 1943 in Oregon and since 1944 in Maryland, seedlings have been planted 64 to the square foot in infested soil in greenhouse benches in winter, and after several months all the uninfected seedlings saved for fruiting tests. The soil for the benches has been taken from the fields where the disease has been serious, and so far these tests have been severe and successful. In Oregon 24,633 seedlings were grown in the benches from 1943 to 1946, and 14,984 are now in the benches. In Maryland about 54,000 seedlings were planted in 1944 and 1945, and about 46,000 more are now in the benches. Many progenies have had 100 per cent infection, even though one parent was quite resistant. The Aberdeen and two selections having as one parent a Scottish resistant selection have been sources of high resistance in the Maryland breeding work. In the Oregon breeding work Aberdeen, some selections of *Fragaria chiloensis,* and Oregon Nos. 1509, 1775, and 1491 have given red-stele-resistant seedlings, though 1509 and 1775 have not proved to be resistant parents in Maryland tests. Oregon 1491 [Ore. 767 (Corvallis x US 836) x Narcissa] has not yet been tested as a parent under eastern conditions. For some reason, possibly different strains of the fungus, the disease has been more virulent and the tests more severe in the greenhouse in Maryland than in Oregon. The third method of testing seems the most economical and quickest in obtaining commercially resistant sorts. Though no commercial damage has occurred where common varieties are entirely killed, a few roots of Temple have shown the disease.

Control of Weeds in Strawberry Plantings by the Use of 2,4-Dichlorophenoxyacetic Acid[1]

By R. F. Carlson, *Michigan State College, East Lansing, Mich.*

The action of 2,4–dichlorophenoxyacetic acid as a herbicide is generally known, and need not be reviewed here. In the summer of 1945 some preliminary experiments were conducted on the control of weeds in strawberry plantations at Geneva, New York, using this new herbicide. At that time the main objective was to eradicate bindweed (*Convolvulus arvensis* L.) from strawberry beds without injury to the plants. The results obtained from this preliminary experiment were augmented by further work in the summer of 1946 at the Michigan State College Experiment Station at Chatham, Michigan, with the object of killing the broad-leaved weeds in several varieties of strawberry plants.

Procedure and Results

1945 Experiment:—Two strawberry plantings of the Premier variety, each about 500 square feet in area, were sprayed with 1,000 parts per million of 2,4–D during the summer of 1945. One was a second-year bed, the other a new spring planting. Both beds were heavily infested with bindweed, wild carrot (*Daucus carota* L.) and yellow dock (*Rumex crispus* L.). The second-year planting was sprayed after harvest, July 15, and the spring planting was sprayed in late June when the runners were forming.

2,4–D was applied with a knapsack sprayer and the strawberry plants as well as the weeds were covered with the spray. At the time of application the weather was clear and warm with temperatures ranging from 68 to 78 degrees F during the day and 60 to 68 degrees F during the nights.

The responses of the weeds to the treatments were quite similar in the two plantings. After 2 days the bindweed took on a wilted appearance, the growth was checked, and it fell away from the strawberry plants which appeared unaffected. Two weeks later the bindweed, wild carrot, and dock were completely withered. No observations were made concerning the depth to which the underground stem of the bindweed was affected. It has been reported, however, that bindweed rhizomes are killed to a depth of about 12 inches (1).

About 2 weeks after application of 2,4–D the strawberry plants in the second-year planting took on a darker green color, and the younger actively growing leaves showed slight twisting of the petioles. The larger plants showed no deformative effect. The spring planting which was producing runners showed similar responses. There was some indication of curling of the young tender shoots but this was of short duration. The runners which had not already rooted continued to grow and made new sets. Although the actively growing plants showed some response to 2,4–D, the effect was only temporary. After 4 or 5 weeks the symptoms disappeared and the plants were apparently again normal.

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[1] Journal Article No. 853 (n.s.) of the Michigan Agricultural Experiment Station.

The following spring the plots were examined to determine whether or not the plants in the treated plots had come through the winter as well as those in the check plot. No ill effects were noticed at that time. The 1945 spring planting which had been sprayed when the runners were formed, flowered normally and produced a good crop of fruit in June, 1946.[2]

1946 Experiment:—These studies were continued in 1946 at the Michigan State College Experiment Station at Chatham. Thirteen varieties of strawberries including Robinson, Premier, Fairfax, Minnesota 1166, Gem, Catskill, Dunlap, Blakemore, Gem 626, Big-late, Dorsett, Red Star and Fairpeake (in their second fruiting year) were sprayed with 2,4–D on August 15. The plantation was heavily infested with alsike clover *(Trifolium hybridum* L.), dandelion *(Taraxacum officinale* Webber), yellow dock *(Rumex crispus* L.), field violet *(Viola sp.),* ground ivy *(Nepeta hederacia* (L.) Trevisan), and Canada thistle *(Circium arvense* (L.) Scop.). A warm sunny day was chosen for spraying when the temperature was above 70 degrees F.

In order to find out what effect various concentrations of the chemical might have on the strawberry plants, the 2,4–D was applied at 400, 800, 1200, 1600, 2000, and 2400 parts per million.

The concentrations higher than the usual herbicidal level of 1000 parts per million were included in the treatments, since clover, ground ivy, and Canada thistle are relatively resistant to the chemical and also, information could be obtained at the same time regarding the effect of high concentrations on the strawberry plants.

Each row of each variety was divided into seven sections so that there were six treatments and one check plot per row. The everbearing varieties (Minnesota 1166, Gem 626, and Gem) were blossoming at the time of application, while the others had previously been harvested.

The results of this experiment are shown in Table I. The low concentrations of 400 and 800 parts per million had no effect on the strawberry plants. Concentrations of 1200, 1600, and 2000 parts per million resulted in slight to moderate twisting of strawberry petioles, and at 2400 parts per million the petioles were badly twisted. The deformative effects caused by the higher concentrations soon disappeared from the strawberry plants and after 4 to 5 weeks they appeared normal. When the flowers of the everbearing varieties were hit with the spray small and misshapen fruits were produced. This was true for all concentrations used. This action of 2,4–D on flowers has been reported for other plants (2).

Many weeds showed deformative effects at the low concentrations of 400 and 800 parts per million and yellow dock, dandelion and field violets were killed. Canada thistle was injured severely at these concentrations but slowly recovered. Alsike clover was not severely af-

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[2] F. L. Gambrell of the New York State Agricultural Experiment Station, Geneva, New York applied some of the herbicidal sprays and made the observations during the spring and summer of 1946.

TABLE I—EFFECTS ON SEVERAL VARIETIES OF STRAWBERRIES RESULTING FROM THE APPLICATION OF DIFFERENT CONCENTRATIONS OF 2,4–D SPRAY TO THE PLANTS; THE EFFECTS REFERRING TO THE TWISTING OF THE PETIOLES AND THE EFFECT ON THE FRUITS

Variety	Effect on the Strawberry Plants (Parts Per Million of 2,4-D)					
	400	800	1,200	1,600	2,000	2,400
Big Late	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Blakemore	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Catskill	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Dorsett	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Dunlap	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Fairfax	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Fairpeake	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Gem (everbearing)	Deformed flower	Deformed flower	Slightly twisted, deformed fruit	Moderately twisted, deformed fruit	Moderately twisted, deformed fruit	Badly twisted, deformed fruit
Gem 626 (everbearing)	Deformed flower	Deformed flower	Slightly twisted, deformed fruit	Moderately twisted, deformed fruit	Moderately twisted, deformed fruit	Badly twisted, deformed fruit
Minnesota 1166 (everbearing)	Deformed flower	Deformed flower	Slightly twisted, deformed fruit	Moderately twisted, deformed fruit	Moderately twisted, deformed fruit	Badly twisted, deformed fruit
Premier	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Red Star	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted
Robinson	None	None	Slightly twisted	Moderately twisted	Moderately twisted	Badly twisted

fected at the low concentrations (400 to 800 parts per million), but was killed at 2000 to 2400 parts per million.

The experiments reported in this paper indicate that under certain conditions 2,4–D may be safely applied at the rate of 1000 parts per million to strawberry plantings to eliminate weeds. Where plantings are set in the spring and no crop is desired the first year the spray might be applied any time during the first season. In the second year the planting could only be sprayed safely after harvest because of the harmful effects of 2,4–D on the blossoms and fruits.

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Line Breeding as a Method of Improving the Pimiento Pepper[1]

By W. H. GREENLEAF, *Georgia Agricultural Experiment Station, Experiment, Ga.*

SEEDS of the pimiento pepper were introduced into the United States about 1904 on the initiative of Mr. S. D. Riegel of Experiment, Georgia. This seed became the foundation stock from which our modern strains were developed. Two major efforts were made which resulted in a pimiento vastly superior to the original Spanish introduction. The first was that of Mr. S. D. Riegel (1) and his son, George Riegel, who selected the "Perfection" pimiento. This new variety was derived from a single, open-pollinated selection which had relatively smooth, thick-walled and pointed fruits with a depression at the stem end. The progeny from this plant was reselected again. No attempt was made to self any of these plants. The second was that of Cochran (2) who developed the "Truhart Perfection" pimiento. This improved strain came from a single, open-pollinated plant selected from the "Perfection" variety. One of its progeny was inbred for three generations. Thereafter, mass-selection was practiced for three more years whereupon the new variety was released to the trade. This new strain was distinguished by its near heart-shape, full shoulder and thick flesh. The "Truhart Perfection" pimiento was by the nature of its origin less variable than the original "Perfection" variety. The present paper gives some results of the pimiento breeding work being carried on by the writer. An outline of a method for breeding pimiento which is most likely to result in the steady improvement of this crop from the long range point of view is also presented.

EXPERIMENTAL RESULTS

During July and August 1945, 18 selections were made from among about 2,500 plants of the "Truhart Perfection" pimiento. The following records of important characters were taken in full, or in part, of each plant while it was being prepared for selfing: fertility (as shown by the number of large, medium and small pods), earliness (five grades), length by diameter of one or more pods (to the nearest 0.1 centimeter), wall thickness of pod (to 0.2 millimeters), vigor (as measured by height of plant to nearest inch) and habit (bushy, open, spreading, droopy and upright). In addition any outstanding feature, for example a long peduncle, response to mosaic infection, and so on, was noted. Thirteen of the 18 plants which had been hand-selfed in the bags set fruit, and between 120 to 240 seedlings of each were set in the field in April 1946. The field, as far as can be judged, received a uniform application of about 700 pounds of a 6–8–6 fertilizer. A similar amount had been applied to the same field for several years previous.

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[1] Journal paper No. 160 of the Georgia Agricultural Experiment Station, Experiment, Georgia.

The writer gratefully acknowledges the counsel of Vida M. Greenleaf, particularly with the statistics.

As the plants approached maturity, striking differences between some of the lines became apparent. These concerned habit, depth of green of the foliage, height of plants and yield. Some observers noted a difference in the size of the leaves as well. This suggested a more thorough analysis of the differences, particularly of the heights and yields. Individual yields were taken of about 115 plants of each of eight lines. Only ripe and mature green fruits were picked at any one time. The last of five pickings, made on November 14, left the plants bare except for the smallest fruits. The yields given in Table I show, therefore, the average production capacity per line over the entire season. The important facts emphasized in Table I are that some of these lines differ significantly in their mean yields and heights, and that these differences are genetic and not due to nutrition. The results point the way to elimination of inferior germ plasm by line breeding. The largest differences in height and yield are nine and eight times their standard errors, respectively. Other characters also are readily transmitted. For example, a line which was exceptionally tall and late and which had long peduncles could be traced to the parent plant with the same characteristics. Selections have again been made from several of the once-selfed lines and twice-selfed seed has been obtained. In addition, an attempt has been made to broaden the basis of the breeding work by selecting outstanding plants from new seed sources.

TABLE I—MEAN YIELDS AND HEIGHTS OF ONCE-SELFED LINES OF TRUHART PERFECTION PIMIENTO

Line	No. of Plants Picked	Mean Yield (Pounds)* S. E. of Mean	No. of Plants Measured	Mean Height (Inches)** S. E. of Mean
02	112	2.4 ± 0.08	100	24.7 ± 0.27
09	133	2.2 ± 0.07	100	24.5 ± 0.29
04	111	2.2 ± 0.06	100	27.8 ± 0.30
05	106	2.0 ± 0.06	—	—
01a	116	1.8 ± 0.06	100	20.7 ± 0.29
01	119	1.7 ± 0.06	—	—
11	111	1.7 ± 0.07	—	—
03	104	1.6 ± 0.06	100	22.9 ± 0.37
12a	—	—	100	21.7 ± 0.30

*A mean difference of 0.2 pounds is significant at the 5 per cent level.
**A mean difference of 1 inch is significant at the 5 per cent level.

DISCUSSION

In the application of plant breeding principles peppers occupy an intermediate position between normally self-pollinated crops like beans, wheat, and so on, and naturally cross-pollinated ones like corn. Thus Odland and Porter (3) report an average of 16.5 per cent cross-pollination by insects, mainly bees, for six varieties of pepper with a range from 7.5 to 36.8 per cent. This raises the question of heterosis and the desirability of close line breeding in pimiento. As pointed out by Jones (4), continued selfing in a naturally cross-pollinated crop, even when accompanied by selection for vigor, will inevitably lead to uniformity in all characters, followed by a loss in vigor and, hence, in productivity. Nevertheless, a uniform yield from every plant (4) is essential for high production. While heterosis is known not to be so critical a factor in commercial production in the mainly self-pollinated pimiento as it is in corn, there are some indications that it may yet become important. In order to overcome any possible ill effects inherent in pure-line breeding, and to utilize the benefits of heterosis in pimiento, it is necessary first to develop a number of inbred lines from diverse sources. These lines should be selected on the basis of plant vigor, largest possible fruit size and highest production. There is little doubt that fecundity in plants is a genetic character. Crosses would then be made between the best yielding lines, preferably on the basis of a yield test. These would serve as the source of still better inbred lines incorporating more of the vigor factors. At intervals the best inbred line(s) or their crosses could be released to the trade as superior strains. Concurrently with this breeding program, genes for disease resistance found in other varieties of peppers could be transferred to the newly bred superior strains of pimiento by the backcross method. There is no doubt that the execution of the above program would eliminate most of the unfruitful plants found in farmers' fields today and would greatly increase the yield per acre.

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Cucumber Breeding Methods

By W. C. BARNES, *Clemson College Truck Experiment Station, Charleston, S. C.*

WHILE breeding cucumbers for downy mildew resistance at this station many thousands of plants have been self-pollinated. Since the technique developed varies somewhat from that reported by other workers it seems worthwhile to describe it so that others doing similar work may benefit. Planting dates, time of flowering and the like will vary according to local climatic conditions but those indicated may serve as a guide.

MATERIALS

The following materials are used:

1. Tags — No. 442 red with linen string, Dennison Manufacturing Co., Framingham, Mass.
2. O. K. paper fasteners — No. 1 B, Oakville Company, Waterbury, Conn.
3. Glassine miniatures (envelopes) 1½ by 2¾ inches, Disbrow Manufacturing Co., Newark, N. J.
4. Metal folding envelopes (seed packets) 3 by 5 inches Disbrow Manufacturing Co., Newark, N. J.
5. Canes — native reed or dog fennel, 18 to 24 inches long.
6. Paper towels, 1000 cubic centimeter and 250 cubic centimeter beakers, 12-mesh wire kitchen strainer, and 4 inch pot labels.

PLANTING

Two generations per year are grown by seeding March 25 to 30 and August 8 to 12. Two methods of seeding have been followed: (a) seeding directly in the field; and (b) seeding in 3-inch clay pots in the greenhouse. Seeding directly in the field is more economical, but stands are frequently damaged by birds, rodents, damping off, and adverse weather conditions. Irrigation is nearly always essential when transplanting potted seedlings to the field. Cucumbers may not be held in the greenhouse in 3 inch pots for more than 5 to 7 days after emergence if normal growth in the field is to be obtained. This 5- to 7-day period allows time for inoculation with diseases, such as downy mildew, but not for readings on resistance.

Plantings are made in 6-foot rows, the hills spaced 2 feet apart with two plants per hill. No difficulty has been encountered in self-pollinating when two plants are left in each hill, and this practice increases the number of plants that can be grown.

POLLINATION

Cucumbers begin flowering about 40 to 45 days after seeding in the spring and 35 days after seeding in the fall. It is very important to pollinate the first pistillate flowers that appear. These are easier to locate and the percentage set is much higher than later in the flowering period.

The staminate and pistillate flower buds are fastened with a paper fastener the day before pollination, as suggested by Munger (1) and Shifriss (2), Fig. 1A. The location of each pistillate flower is marked by laying a cane across the plant or sticking it in the soil at a 30 degree angle. If paper fasteners are not available the flower buds might be tied with small size wrapping twine. Under local conditions, anthers in fastened flowers do not dehisce until 9:00 to 9:30 a. m., and the pollen remains in good condition until 1 to 2 p. m., but better set has been obtained when pollination was completed by noon.

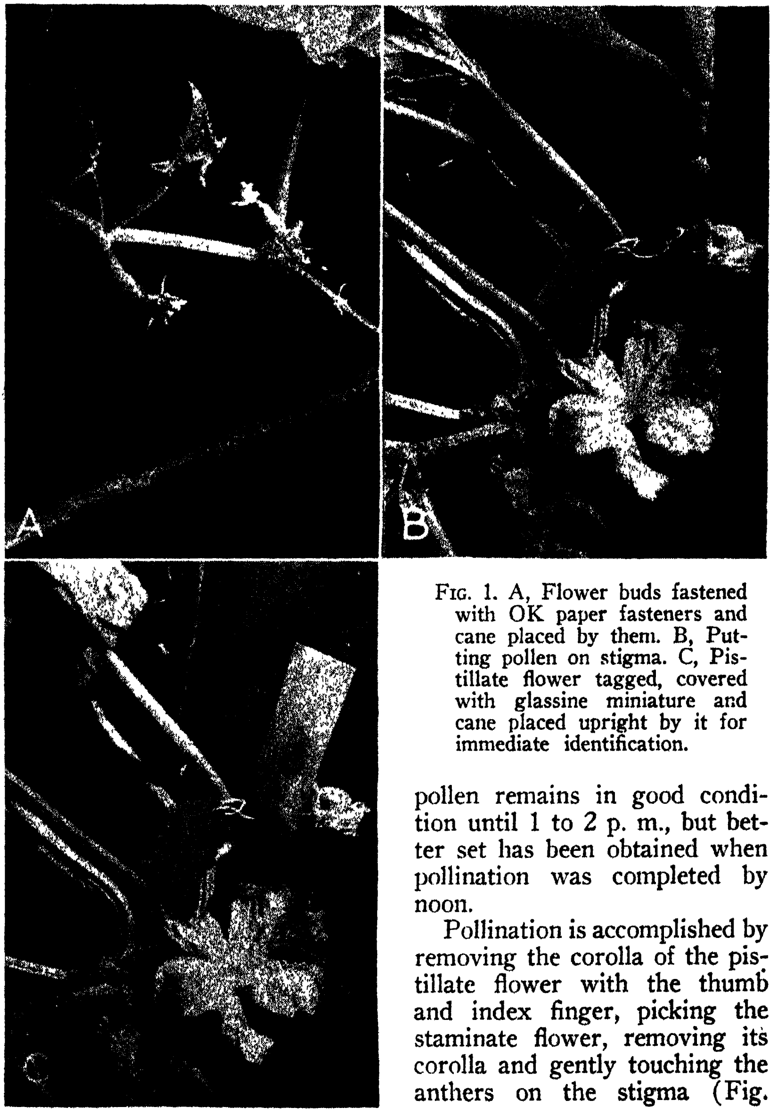

Fig. 1. A, Flower buds fastened with OK paper fasteners and cane placed by them. B, Putting pollen on stigma. C, Pistillate flower tagged, covered with glassine miniature and cane placed upright by it for immediate identification.

Pollination is accomplished by removing the corolla of the pistillate flower with the thumb and index finger, picking the staminate flower, removing its corolla and gently touching the anthers on the stigma (Fig.

1B). The pollinated flower is then tagged, covered with a glassine miniature envelope and its location marked by sticking the cane left the previous day in a perpendicular position (Fig. 1C). This cane method has been found much simpler than the stake system suggested by Shifriss. If a cross is made, the necessary data are written on the tag attached to the flower and on a second tag which is fastened to the top of the cane. When crosses are made in a field where selfings are also being made, a yellow tag on the cane marking the location of a cross aids in identifying it.

By following this pollination procedure, sets of more than 90 per cent have been obtained during the early flowering period and seasonal averages of better than 75 per cent of successful pollinations are always attained. Frequent irrigation during pollination has proved a great aid in assuring a good supply of pistillate flowers and good sets of fruit.

Selection

When the fruits from self-pollinated flowers reach the marketable stage they are examined for fruit and plant type. Where the fruits are not of good shape and color, or are not borne on plants possessing the desired disease resistance and growth characteristics, the canes marking them are removed. Tags are placed on the canes marking the location of a particularly good fruit or plant type. Notes may be written on these tags. It is essential that the planting be gone over two to three times per week until the fruits all reach the marketable stage. Later examinations are sometimes necessary to eliminate fruits on disease susceptible plants. Selfed fruits are often slightly misshapen because of injury or poor pollination. In such cases open pollinated fruits on the same plant are used as the criterion. When examining fruits for desirable characters those that are to be saved are placed on vines or canes to prevent injury by soil rots. If temperatures are high, they also are covered with vines to prevent sun scald.

Harvesting and Seed Extraction

Selfed fruits are ready for harvest within 35 to 45 days after pollination. A progeny number is written on each fruit with an indelible pencil and the fruits are placed on laboratory tables to ripen thoroughly. Seed are extracted by cutting the fruit lengthwise and scraping the seed into 1-liter beakers, (Fig. 2). A 4-inch pot label is placed in each beaker and the progeny number recorded on it. The seed are transferred to 250 cubic centimeter beakers and allowed to ferment for 2 to 4 days. When fermentation reaches the point where seed and pulp separate, the pulp is washed out by running tap water with considerable force through the seed, which are held in a kitchen strainer. If the crop was attacked by a seed borne disease, such as anthracnose, the seed are returned to the beakers and treated with bichloride of mercury solution (1–1000) and washed again. If many faulty seed are present, they are floated off by running water slowly into the beaker of clean seed. The seed are dried on paper towels arranged on a frame covered with window screen wire. When all the seed have been dried,

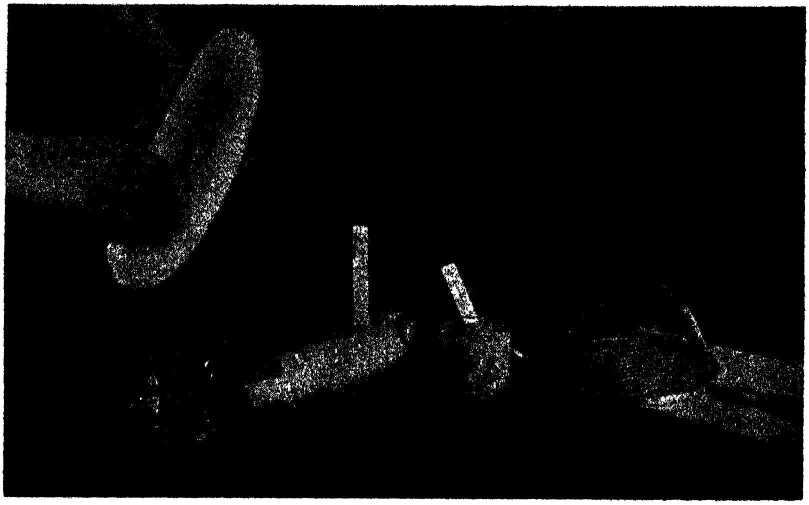

FIG. 2. (Left to right) Extracting seed from selfed fruit, fruit labeled and ready for extraction, fermenting, extracted seed in beaker, and strainer and towels used in washing and drying seed.

they are packaged in metal fold envelopes and treated with Arasan or a similar product before storing. This not only prevents destruction by insects and rodents, but also aids in germination at planting time.

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A Spontaneous Tetraploid Hybrid in Pepper (Capsicum frutescens)[1]

By W. H. GREENLEAF, *Georgia Agricultural Experiment Station, Experiment, Ga.*

IN the spring of 1946 a conspicuous lot of seedlings appeared in a pepper bed. They differed strikingly and uniformly from all other lots of seedlings by the overly enlarged cotyledons and the long-delayed appearance of the young shoot with its true leaves. The cotyledons of these seedlings were a duller green than the normal, and had a fleshy, almost beady-crisp texture. From previous experience with polyploids of Nicotiana species the writer suspected them to be tetraploid. The fact that the pedigree of the seedlings was known made this case particularly interesting. A note taken on the parent plant of these seedlings read: Probably the most thick-walled of all examined. This lent additional support to the tetraploidy notion.

GENETIC AND CYTOLOGICAL EVIDENCE OF TETRAPLOIDY

The tetraploid-suspect population was an F_2 of the cross "Pimiento" by "Santanka". The former is a large, sweet-fruited variety of indeterminate growth. The latter is a dwarf, hot-fruited Japanese pepper which bears its fruits in umbels. It is the umbellate character which makes "Santanka" a determinate growth type. Since the F_1 was heterozygous for two dominant, independent, Mendelian factors, the F_2 offered an opportunity to distinguish between diploid and tetraploid segregation ratios. A diploid sib population was available for comparison. The F_2 plants could be readily classified into the groups hot versus sweet, and umbellate (determinate) versus racemose (indeterminate). Table I gives the results. The Chi-square values show a good fit of observed with calculated frequencies for diploid and tetraploid segregation ratios, respectively. No sweet types appeared in 54 plants

TABLE I—F_2 SEGREGATION RATIOS IN DIPLOID AND TETRAPLOID PEPPER HYBRIDS

Phenotypes	Diploid		Tetraploid			
	Calculated 9:3:3:1	Observed Frequency	Calculated on 1225:35:35:1	Observed Frequency	Calculated 35:1	Calculated 3:1
Hot racemose...	61.31	62	51.04	53	52.5	40.5
Sweet racemose...	20.44	20	1.46	0	—	—
Hot umbellate....	20.44	21	1.46	1	1.5	13.5
Sweet umbellate..	6.81	6	0.04	0	—	—
Total.......	109.00	109	54.00	54	54.0	54.0
	$x^2 = 0.127$ P = 99 per cent		$x^2 = 1.575$ P = Approximately 43 per cent	$x^2 = 0.1715$ P = Approximately 60 per cent	$x^2 = 15.43$ P = ∠1 per cent	

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[1] Journal paper No. 161 of the Georgia Agricultural Experiment Station, Experiment, Georgia.

of the tetraploid population, and only one umbellate plant. This was as expected for a tetraploid in which Chi-square for a 35: 1 ratio equals 0.1715 with a probability of about 60 per cent. Chi-square for a 3: 1 ratio on the same population gave a probability of less than 1 per cent. Acetocarmine smears of pollen mother cells were also made. No exact count was possible of MI and MII figures, but approximately twice the diploid number of units were present at MII. Additional evidence of tetraploidy was the much reduced seed set per pod as compared with that of the corresponding diploid population. This was noticed during the tabulation of the 54 plants for hotness.

Discussion

While tetraploid peppers have been reported earlier in the literature (1, 2), they were the result of colchicine treatment, whereas the one reported in this paper occurred spontaneously. While the combined genetic, cytological and morphological observations furnish adequate proof of tetraploidy in this case, they are not adequate to decide whether the genetic system behaves according to the auto-tetraploid or allo-tetraploid mechanism. It is suggested that there may be partial allo-tetraploid pairing behavior in this wide intraspecific cross. The tetraploid F_1 parent plant probably was the result of chromosome doubling at the first zygotic division. This may have been due to the failure of synchronization in splitting of the chromosomes on the mitotic spindle, probably facilitated by the dissimilarity of the component genomes. A second possible, though improbable, mode of origin is that two unreduced gametes united to form the tetraploid zygote. There is good evidence that the whole F_1 parent plant was tetraploid because seed of it was taken from at least two, and probably four, pods and all of the F_2 seedlings behaved alike regarding the delayed organization of a growing point with true leaves, etc. It is probable that such tetraploids occur more frequently in wide crosses like the above than within any given variety.

There appears to be no practical application of tetraploidy in the commercial production of pepper, unless some special quality like extremely thick flesh is valued sufficiently to outweigh the reduced yield that could be expected from it. The tetraploid plants grew off more slowly than the diploid ones. They exhibited no advantage in vigor over the diploids and their fruit set was definitely lighter.

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The Use of Lycopersicon Peruvianum as a Source of Nematode Resistance in Tomatoes[1]

By Victor M. Watts, *University of Arkansas, Fayetteville, Ark.*

The severity of the nematode problem in southern United States justifies the expenditure of considerable effort toward the development of tomato varieties resistant to nematode injury. A high degree of resistance has been reported in the species *Lycopersicon peruvianum* (1, 2, 3, 5), but unfortunately this species is not easily crossed with *L. esculentum*. A few successful crosses have been made (3, 4, 6), and in the fall of 1944 cuttings of an F_1 plant of Michigan State Forcing × *L. peruvianum,* P. I. 128,657, produced by Smith (6) were obtained from the Division of Truck Crops, University of California. The results of crossing this clone with various lines of *L. esculentum* seem to merit a preliminary report at this time.

Nematode resistance tests were conducted in raised beds in the greenhouse, where the mean temperatures were kept above 90 degrees F. The beds were filled with thoroughly mixed, nematode infested soil. At the initiation of each test severely knotted tomato roots were chopped and a quantity of the material was planted with each plant. The amounts used varied from about 5 grams for 3-inch seedlings to several hundred grams for mature plants with large root systems.

Plants of a commercial variety were used as checks in each test. At least 10 per cent as many check as test plants were inoculated, and injury counts of test plants were not made until all checks had become severely knotted. In all the tests this occurred within 30 days after inoculation.

All seedling groups were subjected to two inoculations before they had reached a height of 9 or 10 inches.

Results and Discussion

In the course of two years three plants of *Lycopersicon peruvianum* P. I. 128,657, and 10 individuals in the F_1 clone secured from Smith survived six inoculations without developing any root knots. The F_1 clone was almost completely self sterile under the conditions in which it was grown.

By using pollen from this clone on various lines of *Lycopersicon esculentum* three outcross seedlings were obtained. One of these, Cr2–45–1, was only moderately resistant to nematode injury, but the other two, Cr2–45–2 and Cr2–45–3, were very strongly resistant. Clonal plants of each of these survived five inoculations in the course of 15 months without developing any root knots.

Of the three outcross clones only one, Cr2–45–2, was self fertile, and it was only moderately fruitful.

During 1945 and 1946 three lots of seedlings Cr3A, the progeny of Cr2–45–2, were tested for nematode resistance. Out of 588 seedlings

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[1] Research Paper No. 851, Journal Series, University of Arkansas. Approved for publication by the Director of the Arkansas Agricultural Experiment Station.

322 were free of knots after two inoculations, and 266 were obviously susceptible. As this is a ratio of 8.76 to 7.24 these results may be taken as evidence that resistance in the early stages of plant growth is controlled by two dominant factors.

In November, 1945, 93 knot-free Cr3A survivors of two inoculations were given a third inoculation in a greenhouse bench, where they were held until June, 1946. At that time, in spite of the fact that all plants had been carefully hand pollinated, only 14 plants had produced seeds. When they were removed from the bed all 93 plants were found free of root knots.

The self sterile plants were discarded, and the 14 self fertile ones were once more inoculated and placed outdoors in 12-inch pots. In October, 1946, the roots were again examined. Four of the 14 had become seriously knotted during the summer. Since all the check plants that had been used at each earlier inoculation had consistently developed root knots within 30 days after treatment, it seems unlikely that these four plants represented escapes. Such results as these suggest that in developing highly resistant varieties from this material it will be necessary to carry resistance tests well beyond the early plant stages.

The fruits of the ultimate survivors of the Cr3A tests varied from 1 to 2 inches in diameter, and in color from deep orange to bright red. In taste and flavor they closely resembled standard commercial varieties.

There seems to be little reason for doubt that varieties can be developed that will combine high degrees of nematode resistance with the other characters that are commonly considered desirable in tomatoes.

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Breeding Tomatoes for Combined Resistance to Fusarium Wilt, Spotted Wilt, and Gray Leaf Spot in Hawaii[1]

By W. A. FRAZIER, K. KIKUTA, and J. W. HENDRIX, *University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii*

IN previous reports published in these PROCEEDINGS, the tomato improvement program in Hawaii has been fully outlined by Frazier *et al* (1), Hendrix *et al* (2), Kikuta and Frazier (3), and McFarlane *et al* (4). The ultimate objective is to develop tomato varieties of high fruit quality, high vitamin C content and heavy yielding capacity, carrying combined resistance to fusarium wilt, spotted wilt, gray leaf spot, mosaic, nematodes and early blight.

Rapid progress in development of lines resistant, in Hawaii, to spotted wilt (3), and other resistant to gray leaf spot (2), as well as the availability of large fruited fusarium resistant lines from W. S. Porte of the United States Department of Agriculture and C. M. Tucker of the Missouri Agricultural Experiment Station made feasible an early hybridization program designed to combine, within one variety, resistance to at least these three diseases. It is the purpose of the present paper to report further progress in this program.

METHODS

Timing and sequence used in the three-way combined resistance test have been outlined previously and need not be repeated in detail here (1). Ten to 15 days after seeds are planted, seedlings are sprayed with gray leaf spot spores. Within 3 to 4 days gray leaf spot susceptibles are eliminated and after an additional 4 days seedlings are removed from the original containers, the roots dipped in fusarium inoculum, and plants placed in a spotted wilt nursery (3) where data on losses from both fusarium wilt and spotted wilt are recorded after 2 to 3 weeks. The method permits elimination of plants susceptible to the three diseases before transplanting to the field. If desired, it also provides for the discarding of late plants, weak stemmed plants, plants with indeterminate growth habit, and those having small and/or rough ovaries and long styles.

RESULTS

The parentage of Hawaii Agricultural Experiment Station selection (HES)[2] 2214 was diagrammed in a previous report (1). Subsequent combined resistance tests of selections from 2214 have confirmed its resistance to the three diseases (Table I). Three derivatives of 2214 — numbers 2468, 2489 and 2524 — are shown in Table I. Of the 80 plants of these three selections tested for reaction to the three diseases, all survived gray leaf spot and spotted wilt, while 70 survived the rigorous fusarium wilt test. In comparison only 3 out of 124 Bounty plants escaped gray leaf spot; only 5 out of 20 escaped spotted wilt, and none out of 40 survived the fusarium wilt test. Separate lots of Bounty plants were needed for each disease test, whereas the 80 plants of the three resistant lines were given the regular sequence test for the diseases. While 2214 selections are relatively fruitful, and of medium to good fruit size, the fruits are slightly rough, vines are relatively small-stemmed and vigor is only fair. Other lines are now emerging which are better commercial prospects than 2214, such as HES numbers 2471, 2544, 2479 and crosses involving these or other selections. Behavior of 2544, the mother (F_1) plant of which gave the heaviest yield of any tomato vine yet recorded in breeding work at the Hawaii station, 115 fruits, weighing 42.2 pounds, with the first 52 fruits weighing 25.3 pounds, is shown in Table I. Because of the complex parentage of the parents it was known that 2544 could be homozygous resistant to spotted wilt, but definitely would be heterozygous for resistance to gray leaf spot and fusarium. Fortunately, it was found, as shown in Table I that 2544 was homozygous resistant to spotted wilt. As was expected, the selection was segregating for resistance to gray leaf spot and fusarium. Several selections from the F_2 progeny were made from the plants surviving the three diseases and seeds of these were planted for combined resistance tests C–17, C–18, (see Table III) along with other selections made from lines listed in Table I. Many other lines were included in the tests but the complete list can not be presented here.

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[1] Published with the permission of the Director as Technical Paper No. 149 of the Hawaii Agricultural Experiment Station.

[2] The letters HES are used in the breeding program to distinguish Hawaii Experiment Station selections. The letters are hereafter omitted, in this paper, to avoid needless repetition.

TABLE I—RESISTANCE OF HAWAII TOMATO SELECTIONS TO GRAY LEAF SPOT, SPOTTED WILT AND FUSARIUM WILT (TEST C 15)

Line HES No.	Generation (F)	No. Seedlings Tested	No. Seedlings Surviving		
			Gray Leaf Spot	Spotted Wilt	Fusarium Wilt
2468 (2214)	4	20	20	20	17
2471	3	80	62	—	—
2471	3	60*	—	60	52
2489 (2214)	4	30	30	30	26
2500	4	60	60	60	51
2524 (2214)	4	30	30	30	27
2544	2	115	79	—	—
2544	2	59*	—	59	53
Bounty	–	124	3	—	—
Bounty	–	20	—	5	—
Bounty	–	40	—	—	0
2479	4	21	21	21	—
2474	3	19	19	16	—

*These plants had survived the gray leaf spot test and were then tested for spotted wilt and fusarium. For example, out of the 62 seedlings of selection 2471 which survived the gray leaf spot test, 60 were transplanted for the spotted wilt and fusarium test; out of the 79 seedlings of selection 2544 surviving the gray leaf spot test, 59 were given a test for the other two diseases.

In Table II, combined resistance data are presented for three F_5 derivatives of 2214, numbers 2681, 2676 and 2671. Of the 75 plants run through the sequence, none was susceptible to gray leaf spot, none was susceptible to spotted wilt, and 10 were susceptible to fusarium wilt. In contrast only 16 out of 272 Bounty plants escaped the gray leaf spot test, 30 out of 65 escaped spotted wilt infection and of 70

TABLE II—RESISTANCE OF HAWAII TOMATO SELECTIONS TO GRAY LEAF SPOT, SPOTTED WILT AND FUSARIUM WILT (TESTS C 17–C 18)

Line or Variety (HES No.)	Generation (F)	Parentage (HES No)	No. Seedlings Tested	No. Seedlings Surviving		
				Gray Leaf Spot	Spotted Wilt	Fusarium
2681	5	2468 (2214)	25	25	25	24
2666	4	2471	25	25	25	19
2667	4	2471	68	55	—	—
2667	4	2471	25*	—	25	22
2682	4	2471	49	37	—	—
2682	4	2471	25*	—	25	15
2676	5	2489 (2214)	25	25	25	17
2673	5	2500	25	25	25	19
2655	3	2544	25	25	25	16
2657	3	2544	50	41	—	—
2657	3	2544	25*	—	25	14
2660	3	2544	39	34	—	—
2660	3	2544	25*	—	25	17
2668	3	2544	57	49	—	—
2668	3	2544	25*	—	25	12
2669	3	2544	52	40	0	—
2669	3	2544	25*	—	25	22
2672	3	2544	40	40	40	35
2674	3	2544	62	50	—	—
2674	3	2544	25*	—	25	14
2689	3	2544	30	30	30	19
2692	3	2544	30	30	30	18
2693	3	2544	70	54	—	—
2693	3	2544	30*	—	30	25
2694	3	2544	88	70	—	—
2694	3	2544	30*	—	30	27
2695	3	2544	30	30	30	18
2700	3	2544	76	54	—	—
2700	3	2544	30*	—	30	11
2671	5	2524 (2214)	25	25	25	23
2678	5	2479	55	55	55	—
2679	5	2479	44	44	44	—
2697	5	2479	30	30	30	—
2698	5	2479	30	30	30	—
2699	5	2479	30	30	30	—
2677	4	2474	25	25	4	—
Bounty	—	——	272	16	—	—
Bounty	—	——	65	—	30	—
Bounty	—	——	70	—	—	0
Pearl Harbor	11	——	70	4	—	—
Pearl Harbor	11	——	20	—	20	—
Pearl Harbor	11	——	20	—	—	0

*These plants had survived the gray leaf spot test and were then tested for spotted wilt and fusarium. See footnote, Table I.

plants tested for fusarium, all were killed. A high level of resistance to the three diseases has thus been maintained through the F_4 and F_5 generations.

Behavior of the F_3 derivatives from 2544 is of special interest (Table II). Of the 12 F_3 selections tested, 5 were homozygous resistant to gray leaf spot, while all remained homozygous resistant to spotted wilt. Resistance to fusarium wilt varied, with selections 2669, 2672 and 2694 showing relatively high resistance and some such as 2700 showing over half the plants affected with the fungus. Thus, in the F_3, lines have been established known to be highly resistant to gray leaf spot and spotted wilt and with good resistance to fusarium wilt.

Other lines were selected for inclusion in Table II to demonstrate resistance only to gray leaf spot (2677), resistance to gray leaf spot and spotted wilt (2479) and only to spotted wilt (Pearl Harbor), and resistance to all three (2214 derivatives, as well as 2673, 2672 and 2666).

Selections from 2479 are among the most promising lines now available for general vine and fruit characters. Fruit size and shape is good, yields are good, vines are early, vine vigor is satisfactory, and resistance to gray leaf spot and spotted wilt is excellent. All are homozygous for determinate vine and even-ripening (white fruit) factors. Since the lines are only in the F_5, selection for desirable vine and fruit characters must be continued for three to five more generations. Since 2479 derivatives have no resistance to fusarium wilt, hybrids have been made with lines such as 2544 and 2471, which carry fusarium resistance, as well as spotted wilt and gray leaf spot resistance. Some of the F_3 lines of 2544 and F_4 lines of 2471 are homozygous for gray leaf spot and spotted wilt resistance. It may thus be expected that hybrids between 2479 and 2544 or 2471 will maintain such resistance, thereby making it necessary only to give special attention to fusarium resistance plus desirable vine and fruit characters. A high percentage of the progeny should be promising, for all parents are relatively desirable types.

DISCUSSION

Spotted Wilt:—At the present time resistance to the form of spotted wilt present in Hawaii is being classed into two types, systemic invasion and localized central stem lesion. In the data presented here, only systemic invasion is considered (3). Localized central stem lesions will occur in "resistant" lines such as Pearl Harbor, and in young seedlings the occurrence may cause serious damage to the plant. However, this localized attack on the central stem, typically originating from primary lesion development in a leaf petiole and extending to the stem, is far less destructive than in susceptible varieties, in which the virus spreads through all parts of the plant. In resistant types, as pointed out in a previous publication (3), leaflet invasion of the virus appears to remain confined usually to the primary lesion area, and the plant continues to grow normally. Resistance to spotted wilt of such lines as 2214, 2544, 2471 and 2479 appears to be similar in type and degree to that of Pearl Harbor (3).

Fusarium Wilt:—Of present day commercial varieties, Pan America is considered one of the most resistant to fusarium wilt. The level of resistance of the Hawaii selections, to the fusarium culture being used for inoculation, is in general equal to or superior to that of Pan America. Complete freedom of any given line to at least some vascular infection has not been found. The Hawaii lines being selected for combined resistance are relatively early, determinate, even-ripening, fruitful types, thus differing greatly from Pan America in many vine and fruit characters.

Gray Leaf Spot:—Isolation of lines homozygous resistant to gray leaf spot in the F_3 generation has been common (1, 2). This is shown clearly in Table II. Inheritance of resistance to gray leaf spot has been studied in detail in parallel studies at this station and will be reported on by Hendrix, *et al.*

Apparent Association Between Gray Leaf Spot and Fusarium Wilt Resistance:—The technique used in testing tomato plants for three-way resistance (1) is useful in collection of data on gray leaf spot and fusarium wilt resistance of individual plants in segregating progeny. After gray leaf spot lesions develop on the cotyledons, the tips of the first true leaves of susceptible plants are marked with a small splash of black India ink and after plants have grown for an additional 3 to 6 days, they are removed from the original seedling pots, roots dipped in fusarium inoculum and gray leaf spot susceptible plants transplanted in one half of a seedling flat, and gray leaf spot resistant plants in the other half. Or, as an alternative, seedlings can be dipped in the fusarium inoculum at time of examining plants for gray leaf spot susceptibility. The young plants at this stage are relatively weak, however, and the shock caused by dipping in fusarium inoculum and transplanting makes it difficult to determine whether subsequent losses are due to shock or to fusarium. Early separation of plants or marking with ink is necessary since cotyledons may fall, leaving no means of identifying the susceptibles.

In Table III are presented backcross data, in which Bounty and Pearl Harbor have been backcrossed to parents carrying fusarium and gray leaf spot resistance. It is apparent from these data that there is a decided tendency for a relatively large number of fusarium re-

TABLE III—SEGREGATION OF TOMATOES FOR RESISTANCE TO GRAY LEAF SPOT AND FUSARIUM WILT IN BACKCROSSES TO SUSCEPTIBLE PARENTS

Line	Gray Leaf Spot Resistance	Fusarium Resistance			Original Segregation for Gray Leaf Spot Resistance		
		No. Plants Tested	Fusarium Resistant	Fusarium Susceptible	Total	No. Resistant	No. Susceptible
T-3070 (1960 × B) × B F_1 Test C 14	Gray leaf spot susceptible	37	5	32	83	43	40
	Gray leaf spot resistant	37	28	9			
T-3071 (1965 × B) × B F_1 Test C 14	Gray leaf spot susceptible	35	5	30	93	45	48
	Gray leaf spot resistant	40	25	15			
Bounty Test C14		40	0	40	56	2	54
T-3114 (PH × T-1740) × PH F_1 Test C 16	Gray leaf spot susceptible	37	13	24	88	44	44
	Gray leaf spot resistant	42	30	12			
T-3114 (PH × T-1740) × PH F_1 Test C 17*	Gray leaf spot susceptible	40	3	37	120	57	63
	Gray leaf spot resistant	40	8	32			
T-3407** [(1960 × B) × B] × B F_1 Test C 17*	Gray leaf spot susceptible	100	3	97	276	149	127
	Gray leaf spot resistant	100	19	81			
Bounty Test C17	Not tested for gray leaf spot	10	0	10			
Bounty Test C17	Tested first for gray leaf spot	25	0	25	73	6	67

*Seedlings dipped in fusarium inoculum as soon as gray leaf spot readings were completed; plants were weaker than in tests C 14, C 16, with losses due probably to a combination of fusarium and shock.

**In each backcross, all F_1 plants were tested for gray leaf spot and fusarium wilt and all susceptibles eliminated.

sistant plants to appear among gray leaf spot resistant plants. Pending the collection of additional data no attempt will be made to explain this association on a basis of linkage, testing method, strains of the disease organisms, or other factors, but from a practical standpoint it is of value to know that in the testing sequence being used the elimination of gray leaf spot susceptible plants at a young stage is actually resulting also in the elimination of a relatively high proportion of fusarium susceptibles.

SUMMARY

Data are presented showing that tomato lines having good resistance to fusarium wilt, spotted wilt, and gray leaf spot, and possessing desirable vine and fruit characters under Hawaiian conditions are under development.

In lines heterozygous for resistance to each of the three diseases, it has been found that in the F_3 generation some segregates will appear that have good three-way resistance. Complete resistance to fusarium wilt has not been maintained in any of the lines, however.

Resistance to spotted wilt in the lines under development is a resistance to systemic invasion, as in the Pearl Harbor variety developed in Hawaii.

With the material being studied, and under the testing methods used, association between resistance to gray leaf spot and to fusarium wilt is such that elimination of gray leaf spot susceptibles results in the elimination also of a relatively high proportion of fusarium susceptibles.

Most of the Hawaii combined resistance lines are early, determinate, even-ripening (white immature fruit color) types, with ability to set fruit well under the moderate temperatures prevailing in Hawaii.

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A Final Report on Studies of Tomato Fruit Cracking in Maryland[1]

By W. A. Frazier, *University of Hawaii, Honolulu, Hawaii*, and
John L. Bowers, *Mississippi State College, State College, Miss.*

Comparative studies of the incidence and severity of fruit cracking in tomato varieties were begun in Maryland in the summer of 1936, and a brief summary was published (5). Certain of the varieties which showed distinct types and differences in severity of cracking were planted in 1937, to determine, for a limited number of fruits observed closely, whether these characteristics would again appear. In addition, data on rainfall and evaporating power of the air, physiological age of fruits at time of cracking as measured by date of the early pink stage, and rate of fruit enlargement, were obtained and correlated with daily measurements of severity of fruit cracking. It is the purpose of this paper to present these data, and to discuss their relation to other factors which have been shown in previous proceedings (3, 4) to be closely associated with tomato fruit cracking.

Experimental Methods

1936:—Greenhouse grown plants were transplanted to the field May 12. Forty-three named varieties were used in the test, although 70 distinct lots were provided for, since seed of some varieties were obtained from several sources. Each lot was replicated five times in five blocks, each of the blocks containing the 70 lots at random. Although only four plants per plot were used for recording data, the relatively large number of replications decreased variability due to soil and other factors. For the nine varieties reported in the present paper, five plots were used for Earliana, Dwarf Champion, and Delaware Beauty, while from 10 to 35 randomized plots were used for each of the remaining six varieties. Plants were spaced 4½ by 4½ feet. The soil used was a light sandy loam. Plants at full maturity were moderately small, with practically no overlapping of vines. A good set of fruits was obtained, and approximately 300 to 700 fruits were harvested for cracking data from each of the lots. The first picking was made July 15, and later pickings made at 5- to 7-day intervals. All fruits were harvested at the full pink or early ripe stage.

Cracking data were obtained on the individual fruits from each vine and included: (a) weight of fruits, (b) size and number of radial cracks (large, medium, small, very small) and (c) degree of concentric cracking (large, medium, small). Large radial cracks were considered as those which radiated well past the "shoulder" of the fruit, or were exceptionally deep, such as is typical of Marglobe; medium radial cracks were considered as those ¼ to ½ inch long; very small, those less than ¼ inch long. Number of concentric cracks was not taken, but this type of cracking on each fruit was classed as large, medium, or small. Fruits showing individual concentric cracks 1 inch or more in length were classed as "large", those of less than 1 inch, but large and numerous enough to adversely affect the appearance of the fruit were classed as "medium", and those of minor importance as "small".

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[1] A report of experimental work done while the authors were members of the staff of the Maryland Agricultural Experiment Station.

Scientific Paper No. A155, Contribution No. 2050 of the Maryland Agricultural Experiment Station (Department of Horticulture).

A small hand press mentioned in the paper was designed by Dr. V. R. Boswell, and the authors are indebted to him for permission to use the instrument. The senior author is indebted to Dr. Boswell for his suggestion of the problem and for his advice and encouragement from the time that work was begun on it at the University of Maryland in 1931. Mr. J. H. Beatty kindly furnished records of rainfall data for Beltsville, Maryland.

From the time the plants were set in the field until July 4, sufficient rain fell to keep the plants growing well. After a rainfall of .42 inch on July 4, a dry period followed until July 23. The light rain of .2 inch on July 10 was insufficient to keep the plants growing well, and by July 15 mid-day wilting of leaves was apparent. From July 23 to July 28 a series of heavy showers fell, thoroughly wetting the soil. Rainfall for July and August are shown in Table IA.

TABLE IA—RAINFALL DATA, BELTSVILLE, MARYLAND (1936)

Date	Rainfall, 1936 (Inches)
Jul 3	0.25
Jul 4	0.42
Jul 10	0.20
Jul 23	0.14
Jul 24	0.55
Jul 27–28	0.54
Jul 31	0.04
Aug 6	0.18
Aug 21	0.95

1937:—Plants grown in the greenhouse were transplanted to the field May 25. Plots were located near those used for the 1936 test, and soil type was similar. Nine varieties were included, with the varieties planted in single row plots of 24 plants each. Rows were 5 feet apart and plants 4 feet apart in the row. Three blocks were provided, with the variety rows planted at random in each block.

Instead of harvesting a large number of fruits at intervals of a few days to determine the severity of cracking, it was decided to study more closely a limited number of fruits of each variety to secure the time of occurrence of cracking in relation to the growth period, physiological age, and climatic factors, and to follow these relations from day to day. Data included: (a) daily measurements of the circumference of individual fruits, (b) daily observation of each fruit for number of radial or concentric cracks, (c) daily measurements of length of both radial and concentric cracks for each fruit, (d) date each fruit turned pink, and (e) climatological data. Radial cracks were considered only as those occurring in the creases of the stem-end area, above interlocular septae. Concentric cracks included all of those other than radial, even though many did not lie in a true concentric position.

On July 14, five fruits were selected on separate plants in each row for daily circumference and cracking data. Fruits selected had circumferences at that time between 6 and 9 centimeters, with average circumferences for all varieties of 7.7 centimeters. This provided for 15 fruits of each variety on which cracking data were obtained. A few fruits were lost, so that final data have been analyzed for the 10 fruits of each variety which reached the pink stage within 2 or 3 days of the mean date for all varieties, which was August 10. Most of the fruits were pink between August 9 and 12. By August 11, cracking had become so severe, especially on certain varieties, that it was impossible to continue cracking measurements on all fruits. Accordingly five fruits of each variety were used for cracking measurements until termination of the experiment August 16. Circumference measurements, however, were continued for all fruits until August 16. Measurements of circumferences and cracking were begun daily at 8 a. m.

Vine growth was rather small, due to relatively low soil fertility. Fruit setting, however, was good, and ultimate fruit size was satisfactory. Timely rains fell throughout the 1937 season, so that soil moisture was at no time limiting. In June, 2.54 inches of rain fell, with rainfall recorded for 11 days in the month. In July, 6.37 inches fell, with heavy rains July 15 and July 31. Rainfall from July 14 until August 16 is shown in Fig. 3. The only recorded instances of wilting of the plant leaves was slight wilting in the early afternoons of July 10 and July 11. On both of these dates, strong winds blew most of the day. At this time, however, even the surface soil was moist underneath the plants, as a result of the heavy rain of July 31, and rainfall from August 6 to 8 of over 1 inch.

Evaporation data shown in Table III were secured by means of a recording atmometer apparatus, constructed so that hourly evaporation could be read from a revolving drum. The common mercury plugs, as used by Livingston, were utilized to prevent absorption of rainfall by the black atmometer. The atmometer was placed in the center of the tomato plot area, with the bulb fully exposed throughout the day. Distance from soil surface to bulb was 42 inches.

TYPE AND DEGREE OF CRACKING AS INFLUENCED BY VARIETY

Concentric Cracking 1936·—Concentric cracking of the various varieties for six harvest dates in 1936 is shown in Table I. Low fre-

TABLE I—CONCENTRIC CRACKING OF TOMATO FRUITS (BELTSVILLE, 1936)

Variety	Per Cent Fruits Cracked Concentrically*					
	Jul 21	Jul 27	Aug 3	Aug 7	Aug 12	Aug 19
Earliana	0	17	24	63	89	73
Grothens Red Globe	4	2	48	77	96	84
Pritchard	0	0	18	38	47	56
Delaware Beauty	0	0	18	26	49	56
Greater Baltimore	0	0	2	15	39	37
Dwarf Champion	0	0	0	16	34	14
Rutgers	0	1	4	5	53	51
Browns Special	0	0	4	11	23	17
Marglobe	0	3	12	17	52	51

*Per cent of fruits showing medium or large concentric cracks. This included all fruits with severe enough concentric cracking to obviously detract from desirable fruit appearance. Fruits picked at full pink and early red ripe stage of maturity quency of concentric cracking is apparent for all varieties early in the season, but was most severe for Earliana and Grothens Globe. Throughout the harvest period these two varieties were most severely cracked concentrically. For the second harvest date, Earliana had 17 per cent of the fruits cracked concentrically, while Browns Special had none. August 19; Earliana had 89 per cent, and Browns Special 23 per cent. Dwarf Champion ranked next to Browns Special in low incidence of concentric cracking. Differences between other varieties are not considered great enough to merit further attention. It is important to recall that these harvests included only those fruits within the full pink or early red ripe stages of maturity, and that many of the fruits cracked several days previous to harvest. Although most of the concentric cracking occurred within and following the rainy period of July 24 to 28, it is not advisable to attempt a correlation of fruit cracking on various dates with rainfall data, because of the age of fruit factor. It is interesting to note, however, that the mature or near mature fruits harvested July 27, three days after the first heavy shower, were not cracked severely concentrically. This agrees with observations and data in other years for Maryland, when it was found that generally the most severe concentric cracking occurred on later maturing fruits even though weather conditions at time of cracking were no more conductive to fruit splitting than had occurred earlier in the season.

Radial Cracking 1936:—Radial cracking of the varieties is shown in Table II. In this case the number of cracks per 100 fruits is presented, instead of the percentage of cracked fruits. From the standpoint of a varietal comparison, relative differences remain the same. Radial cracking was relatively more severe early in the season than concentric cracking, as can be seen, for example, in comparison of the types of cracking for Dwarf Champion. No concentric cracking of this variety was recorded for the first two harvest dates, while radial cracking was severe. In comparing the varieties for the entire harvest period, Dwarf Champion and Marglobe showed most severe radial cracking.

TABLE II—Radial Cracking of Tomato Fruits (Beltsville, 1936)

Variety	Number Radial Cracks Per 100 Fruits*					
	Jul 21	Jul 27	Aug 3	Aug 7	Aug 12	Aug 19
Earliana	0	83	82	21	39	0
Grothens Red Globe	5	22	47	48	31	6
Pritchard	0	10	13	38	67	16
Delaware Beauty	14	5	54	74	66	20
Greater Baltimore	1	29	42	81	103	40
Dwarf Champion	24	78	113	128	148	57
Rutgers	7	7	43	104	83	25
Browns Special	0	0	25	33	44	20
Marglobe	11	26	46	123	163	35

*Figures represent number large plus medium radial cracks per 100 fruits. Fruits picked at full pink and early red ripe stage of maturity.

Radial cracking of Earliana was rather severe on July 27 and August 3. Browns Special and Pritchard were far less severely cracked radially than Marglobe or Dwarf Champion. This severe radial cracking of Dwarf Champion occurred, even early in the season, when the bushy, potato-leaved foliage shaded the fruits very well. Shading reduces severity of tomato fruit cracking, but is relatively less effective in reducing the radial as compared to concentric type.

Concentric Cracking 1937:—Concentric cracking in centimeters per fruit (cracking index) is shown in Fig. 1, for the 1937 season, and for the nine varieties. This type of cracking, as in 1936, was most severe for Earliana and Grothens Red Globe. No statistical difference between the other varieties was found in a comparison for August 11. Concentric cracking per fruit for Earliana on August 11 was 24.2 centimeters, a linear cracking index greater than the fruit circumference. The Figure shows that a day by day increase in severity of

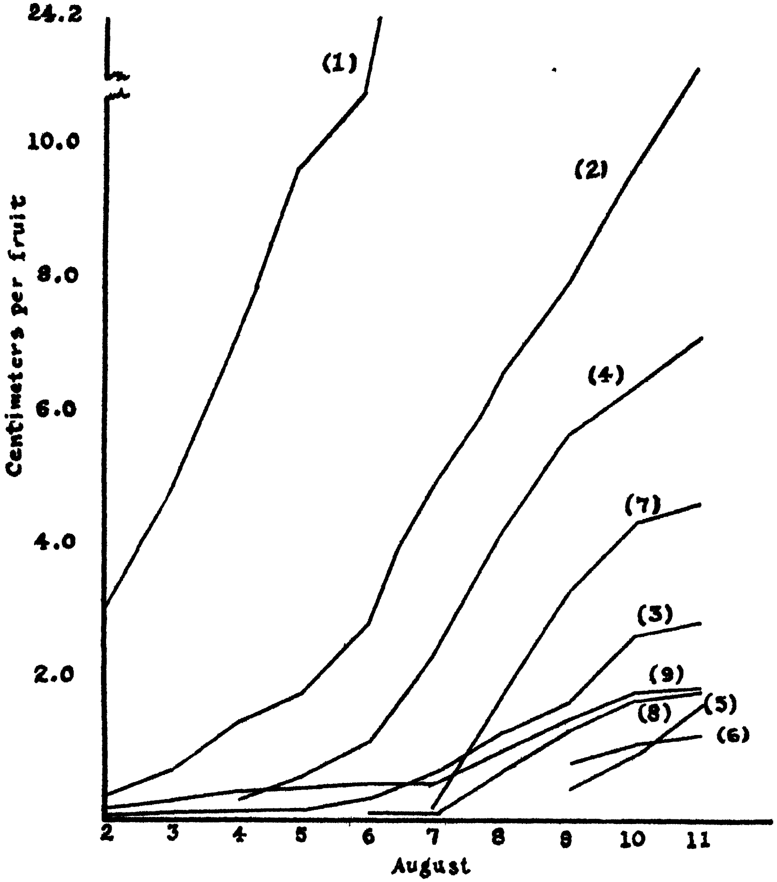

FIG. 1. Daily additive linear concentric cracking indices of tomato fruits of various varieties. (1) Earliana, (2) Grothens Red Globe, (3) Pritchard, (4) Delaware Beauty, (5) Greater Baltimore, (6) Browns Special, (7) Rutgers, (8) Dwarf Champion, (9) Marglobe.

concentric cracking took place, rather than sudden, severe cracking, for the period from August 2 to August 11. It was found, also, that concentric cracking of Browns Special and Greater Baltimore was absent until August 9. This, again, is in line with the relatively late appearance of this type of cracking for these two varieties the previous year.

Radial Cracking 1937:—Radial cracking indices in centimeters per fruit are shown in Fig. 2. Marglobe and Dwarf Champion showed the highest indices, as was true for 1936. Earliana and Grothens Red Globe were low in severity of radial cracking. In 1936, Earliana showed rather severe radial cracking early in the season. For all

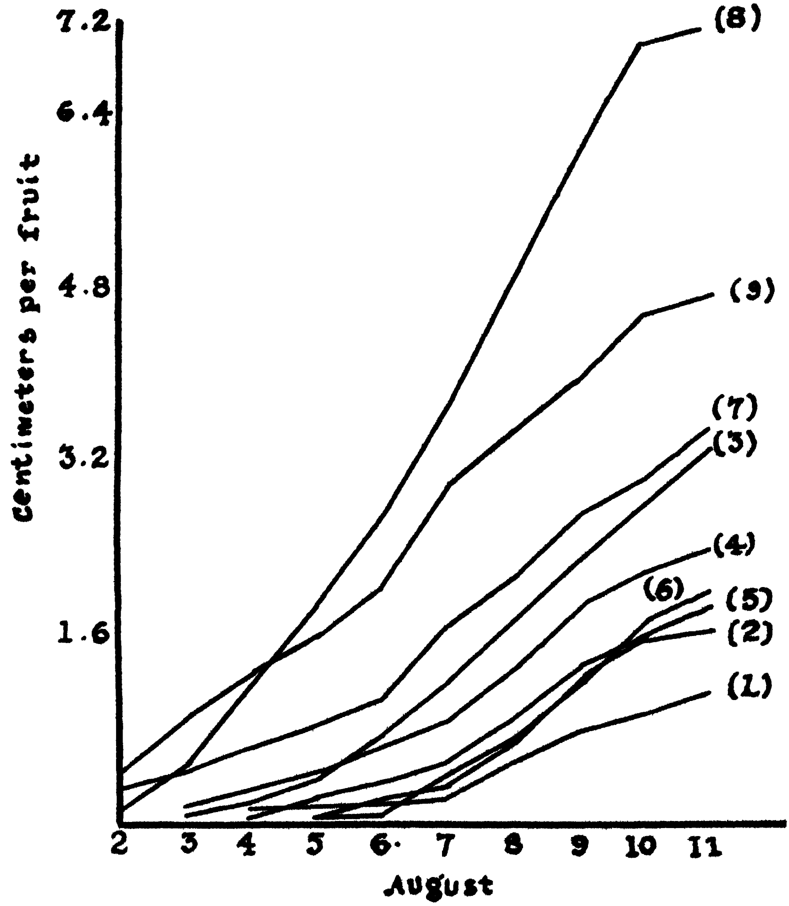

FIG. 2. Daily additive linear radial cracking indices of tomato fruits of various varieties. (1) Earliana, (2) Grothens Red Globe, (3) Pritchard, (4) Delaware Beauty, (5) Greater Baltimore, (6) Browns Special, (7) Rutgers, (8) Dwarf Champion, (9) Marglobe.

varieties, radial cracking increased from day to day. These data for radial and concentric cracking were secured on the same fruits day after day, so that it could be determined whether increase in indices was due to development of new cracks or enlargement of old ones. It was found that the increase was due to both. For example, new radial cracks were seldom, on the first day of measurement, more than .2 to .5 centimeters in length. These cracks, however, showed linear increase, as a rule, from day to day. In some cases a given fruit showed increased length of some cracks, while other cracks on the same fruit remained the same.

INCREASE IN FRUIT SIZE AS RELATED TO CRACKING

By daily measurements of growth (circumference) of fruits which were to be observed for cracking, it was thought that valuable information might be obtained on time of occurrence of cracking relative to daily increase in size of fruit. It would also show the period within the normal growth curve at which cracking occurred, at least for this given set of conditions. Fig. 3 shows these relations. Averages of fruits

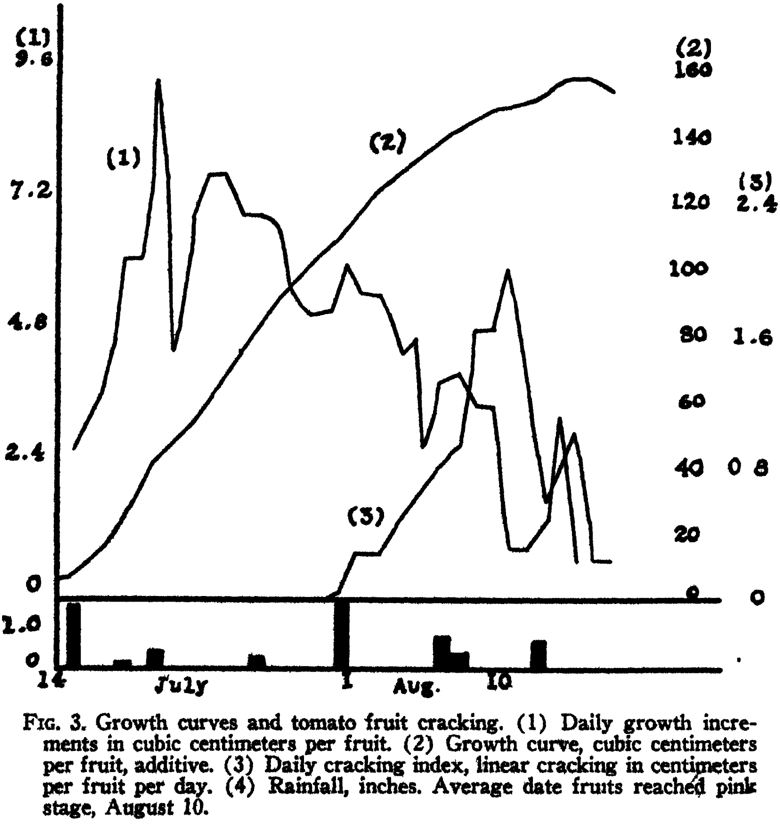

FIG. 3. Growth curves and tomato fruit cracking. (1) Daily growth increments in cubic centimeters per fruit. (2) Growth curve, cubic centimeters per fruit, additive. (3) Daily cracking index, linear cracking in centimeters per fruit per day. (4) Rainfall, inches. Average date fruits reached pink stage, August 10.

of the nine varieties were used in each case. Graphs were made for each of the varieties, but the relative changes were similar, with the exception of a slightly earlier decrease in growth rate for Earliana and Pritchard fruits. A typical S shaped curve is not entirely shown, because measurements were not started until the initial slow rate of enlargement was almost over. In no case, however, was there a decrease in fruit volume until August 15 and 16, when the red ripe fruits each lost an average of 2.5 cubic centimeters per day.

Although there was a day by day net increase in fruit size, the amount of this increase varied considerably, as shown by the daily growth increment curve. These daily variations in increments were influenced most by rainfall as can be seen. Yet it is clearly shown that greatest daily increments occurred from July 18 to July 27, when, regardless of rain, the values were high. This we may assume was a period for normal rapid enlargement. If we now compare the initiation of cracks and daily cracking indices, with the curve for growth increments, we note that cracking began and increased during the period when daily growth increments were decreasing. Within the period of cracking, there was no close agreement between volume increase and cracking index. For these daily comparisons, of course it is well to consider that measurements made once daily do not definitely indicate what fluctuations may have occurred during the 24 hours of the day. However since we have observed, throughout these studies, rather infrequent cracking of tomato fruits earlier than 12 days prior to the pink stage, we believe that cracking usually takes place beyond the period when the highest daily growth increments occur.

Fig. 3 shows that the first cracking occurred July 31. The heavy rainfall of over 2 inches for that date fell between 1 and 7 a. m. Cracking records were taken at 8 a. m. This heavy rainfall was not effective, for fruits of this age, in immediately causing severe cracking.

Cracking indices daily increased, regardless of rainfall, until August 10. August 10 and 11 were days of heavy wind and rapid evaporation. Evaporation from a black bulb atmometer for August 10 is shown in Table III. This table shows that cracking decreased from the previous

TABLE III—EVAPORATION AND CRACKING INDICES

Date	Evaporation 24 Hours Previous to Securing Cracking Data				24 Hour Cracking Index*	24 Hour Volume Increase† (Cc)
	Evaporation From Black Bulb Atmometer (Cc)			Hours of Apparent Zero Loss		
	8 A M 8 P M 12 Hours	8 P M 8 A M 12 Hours	Total Evaporation			
Aug 6	43	1	44	11	0.85	4.16
Aug 8	33	3	36	0	1.60	3.40
Aug 9	38	2	40	0	1.99	1.00
Aug 10	45	12	57	0	1.10	0.97
Aug 13	19	1	20	12	1.00	0.67

*Linear cracking per fruit (centimeters) recorded 8 a m on day following indicated date for evaporation data. Average of nine varieties of tomatoes, 45 fruits.

†Spherical volumes calculated from circumference measurements at 8 a m on day following indicated date for evaporation data. Average of nine varieties of tomatoes.

day, under these conditions, but the index was, even so, higher than for August 6, when evaporation was much less. Further, the volume increase in cubic centimeters was only about one-fourth that of August 6. The low evaporativity of the night hours was inducive to the high cracking indices recorded, for in checking back on morning cracking indices by making afternoon measurements also, we could find no measureable increase in cracking. While the data show that these mechanical measurements can be used in a general way to indicate climatic conditions favorable for cracking, physiology of fruit and vine should also be given due consideration in detailed studies of variations in cracking behavior.

INFLUENCE OF PHYSIOLOGICAL AGE ON SUSCEPTIBILITY TO CRACKING

Cracking indices in Fig. 3 were highest near the pink stage of maturity of the fruits. The present data are not to be taken as truly indicative of time of cracking for any given age, because of the influence of climatic conditions, yet we have repeatedly found highest initiation of cracking either a few days before, during or after the pink stage. In the greenhouse, where practically all cracking is confined to the radial type, particularly during the winter, climatic variations are of less importance, and time of initiation of cracking should be more indicative of the importance of physiological age. Table IV compares the time of first cracking under field and greenhouse conditions in earlier studies. Much of the field cracking was concentric in type. Data for the 1932 season showed that concentric cracking of the "netted" type occurred more frequently on mature green or near mature green fruits than on red ripe ones. The data in Table IV show also the in-

TABLE IV—PER CENT OF TOMATO FRUITS CRACKING IN RELATION TO PHYSIOLOGICAL AGE

Maturity	Field (1932)		Greenhouse (1932)†
	Dry*	Dry-Wet**	
10 days preceding pink	0.26	2.86	0.00
9 days preceding pink	1.31	4.91	0.79
8 days preceding pink	2.39	7.49	0.64
7 days preceding pink	3.54	5.58	0.80
6 days preceding pink	3.95	11.83	0.65
5 days preceding pink	2.05	6.37	0.32
4 days preceding pink	4.20	10.75	0.32
3 days preceding pink	5.95	8.83	1.32
2 days preceding pink	5.33	19.38	2.17
1 day preceding pink	8.09	13.11	1.88
Pink	11.87	22.01	5.40
1 day after pink	8.70	16.93	7.73
2 days after pink	7.14	26.21	7.18
3 days after pink-red	6.66	14.47	10.32
4 days after pink-red	5.49	18.46	8.63

*Plots left dry throughout season.

**Plots dry for part of season, followed by repeated heavy irrigation. First irrigation made August 11, when approximately 20 per cent of the total fruits harvested had reached pink stage. Fruits were tagged at time of blossoming, and individual fruit records kept as to the first day cracking occurred. A record was made on the tag of the date each fruit showed early pink color. The difference between the two dates provided for the above data on time of first cracking in relation to physiological age. Repeated populations of fruits reaching the pink stage on given dates were utilized in securing these percentages. The figures are therefore not to be added to 100.

†Winter crop, grown under low light intensity and free of decided fluctuations in temperature and moisture supply.

fluence of variation in soil moisture treatments, particularly heavy irrigation following a drought.

DISCUSSION

Since data presented in the present paper must be considered as contributing only to certain phases of the problem of tomato fruit cracking, and since no further publications are contemplated on the Maryland studies by the present authors extending from 1931 through 1937, it is thought proper to review the various factors which appear to us to be closely concerned with cracking.

Types of Tomato Fruit Cracking and Possible Causes:—

1. Radial cracking, originating above interlocular septae, closely associated with observed inherent anatomical weakness of septae tissue (4), and with differential growth rates which, as fruits approach ripeness, cause a "smoothing out" of the creases of the stem end, lying above these septae.
2. Concentric cracking resulting from intake of water by corky spots on the fruit during periods of rain or dew.
3. Radial, and possibly concentric cracking during periods of rain or dew caused by intake of water through stem end scar tissue. In these latter two cases osmotic and imbititional forces are considered as playing a part in swelling (10, 4, 7).
4. Cracking resulting from, or increased by, pressure of locular contents on the ovary wall. Fruits have been observed, in which the crack extended entirely through the ovary wall, and locular contents appeared to be pushing through. Cracking of this degree of severity has been produced experimentally in only one case, that in which vines grown in the field were kept dry over a long period, and then heavily irrigated. After the irrigation, a period of rain aided in increasing cracking, but fruits on vines which had been kept well irrigated throughout the season or which had been kept dry until the rain occurred, without further irrigation, did not crack so as to expose locular contents. It was plain that the irrigation affected fruit cracking by intake of water through the roots, and apparently caused an increase in water content of the locular cavity sufficient to produce abnormal pressure on the ovary wall. The gross ovary wall structure failed to expand sufficiently to provide for locular contents. Cracking of this severity has been observed, infrequently, in other cases after prolonged heavy rain, and then only late in the season. MacGillivray (12) has shown that relative amount of ovary wall tissue varies through the season, becoming less at later harvest dates. Thickness of ovary wall to be broken through is, therefore, relatively less. It is probable that pressure from within the locular cavity, however, is not the cause of most cracks since cracking of "puffy" tomatoes is often observed, where no such pressure could possibly occur.
5. Cracking apparently caused by effect of relatively high temperatures. Sudden, severe cracking of mature red ripe fruits has been noted in the greenhouse in mid-afternoon, when temperatures and evaporation were high. Cracking of this type, although not of frequent

occurrence, has been observed only in the case of fruits fully ripe. The extreme severity and suddenness noted in a few such cases indicates that the cutin may have offered considerable resistance to heat expansion of the underlying flesh; for, it is recognized that in these fully ripe fruits, protopectin, which aids in cementing cells together, has, in part, been broken down, and once the cutinized covering is broken, would permit severe splitting of the fruit.

6. Once cracking has occurred, intake of external moisture by the exposed tissue often results in much more severe cracking. Moreover, initiation of a crack provides a weak point at which further splitting will occur depending upon differential expansion of underlying tissues and skin.

7. Radial or concentric cracking resulting from malformed or injured fruits. In many cases the cracks are clearly caused by swelling beneath scars which have corked over and are unable to expand so as to permit normal increase in fruit size. The prevalence of fruit malformation varies with varieties and environmental conditions. Some malformed fruits result from abnormal petal expansion; the ovary is injured at an early stage. Cracking which follows hardening of peripheral tissue in sunburned areas is commonly observed. Cracking of fruits less than 10 days after time of flower opening was observed by the senior author on the Yuma Mesa of Arizona in the fall of 1938, following drying winds which injured young fruits by moving them against soil, or plant parts. Surfaces thus injured corked over, and, following the desiccating wind, when normal expansion of the fruit was resumed, numerous cracks occurred within the corked-over areas.

8. If the latter simple and easily visible cause of tomato fruit cracking is correct, then can we not suppose that some cracking—particularly of the concentric type—results, in a similar manner, from less well defined hardening or "setting" of ovary wall cells? This "setting" we consider as any physical or chemical change occurring in local areas of the outer ovary wall cells as a result of water deficits, caused either by "internal drought" or water movement, or by the direct effect of desiccating climatic conditions, such as sunshine effects, low humidity, or high winds. Histological variations in areas of tomato ovary wall tissues, closely associated with water relations and temperature effects, have been clearly demonstrated (11, 14). We have found it relatively easy to show differences in water content of tomato fruit tissue by varying soil moisture supply (3), and nutrient salt concentration can be shown to affect water content of the tissue (13). Further, increase in soil moisture supply, following drought, will increase incidence of cracking, but we have found that the immediate increase in water content of the tissues, even though cracking occurred, was slight. In a comparison of water content of tissue plugs from cracked versus non-cracked fruits, or of cracked versus non-cracked areas on the same fruit, providing place-effect (shading, and so on) was similar, we have found no consistent differences. In a general way, it was found that ovary wall tissue low in water content was far more susceptible to potential severe cracking than that high in water content (field, compared to greenhouse crops, or dry versus heavy irrigation treat-

ments). We must conclude that the technique used for tissue plug studies, plugs approximately ¼ inch square, was not sufficiently refined, as we might suspect, to locate water differences that might cause fruit splitting. Rather than assume that sudden and appreciable movement of water from parts of the fruit high in water content to parts lower in water was the cause of concentric cracking, it has seemed most logical to believe that the relatively greater normal enlargement of cells lying beneath those modified or "set" by desiccation is the causal factor (16). This does not exclude the possibility that, after prolonged conditions conducive to hydration, swelling and cracking within the modified cell area may occur (15).

In tomato fruit cracking, water gradients in distinct areas of the fruit have not been of great importance, for such gradients, often of considerable degree, are present under varying climatic conditions, regardless of the prevalence of cracking (3). It was found that stem end ovary wall tissue is usually higher in water content than stylar end tissue, but, in a greenhouse-grown crop in the winter of 1936–37, when, under relatively low temperatures, plants were slowly wilted, stem end tissue was actually lower in water than stylar end tissue. These comparisons were made on small blocks of ovary wall tissue, by means of a "micro" hand press, and tomato refractometer.

Although we have postulated cell and cell wall changes resulting from water deficits as being concerned with cracking, there remains the question as to severity of deficit and the time factor required in order to produce these changes. What is the effect of short, perhaps frequent, water deficits resulting from daily or even hourly variations in the evaporating power of the atmosphere? Fluctuations of tomato fruit size at different periods of the day have long been known. In the present paper, it was shown that daily increase in fruit volume continued up to the initiation of cracking, as indicated by circumference measurements. There was no apparent arrest of growth of the fruits throughout the period, as determined by readings made each day at 8 a. m. It is realized that these measurements, corrected to spherical volumes, are not exact indicators of fruit volume, for they can not take into account differences in fruit shape (differential growth rates), nor do they necessarily mean that the actual daily volume increases, or actual fruit sizes finally reached, were as great as they may have been under conditions of even lower water loss from leaf and fruit surfaces, or with other complex conditions more favorable for growth (size). It is known that conditions previous to fruit set, number of cells in the ovary at blossom time (8), and conditions following fruit set (6), have important effects on size of fruit ultimately reached. The interesting fact is that, as data in the present paper show, severe cracking occurred, even though no readily apparent and certainly no prolonged arrest of fruit growth was noted. Since soil moisture was not in itself a limiting factor, it seems that water deficits of sufficient severity to affect cell behavior occurred as a result of daily fluctuations in the evaporating power of the air, regardless of soil moisture content. Temperature, wind, humidity, shading of fruits (1, 3), position of the fruit on the cluster (3), age of fruit, amount of foliage (4), number and size of fruits on the vine, relative extent of root system (9), root-top ratio, soil salt concentration (13), and nutrient availability, particularly calcium, are all factors concerned with the water relations of fruit and vine, and are doubtless able, in some degree, to affect fruit cracking. Most of them have actually been shown to do so, as evidenced in the literature cited. This concept regarding, particularly, concentric cracking of the tomato is supported by the following observations:

1. Relatively high concentric cracking and "netting" of exposed as compared to well shaded fruits, under field conditions.

2. Reduction of such cracking by bagging fruits with muslin, or shading the entire vine.

3. Low degree of concentric cracking in greenhouse winter grown crops. Concentric cracking of tomatoes was repeatedly shown to be relatively low under greenhouse conditions in the fall and winter months. Wide and sudden variations in the evaporating power of the air, due to changes in relative humidity or wind movement, are less prevalent under these winter conditions than in the field grown crops (17).

4. Greater prevalence of concentric cracking and "netting" of those fruits in the greenhouse which are exposed to longest hours of sun.

5. Relatively low per cent of initiation of concentric cracks in red ripe fruits, when, at the same time, concentric cracking of mature green fruits may be high. The red ripe fruits, it may be supposed, reached full growth under conditions promoting continued uniform fruit development.

6. For the various crops of tomatoes that we have observed, fruit cracking has been most severe late in the season, under immediate climatic conditions that apparently should have produced no more severe cracking than in the early part of the season. An important factor, in this case, seems to be the usual partial defoliation and sprawling of vines as they become older, leaving fruits more exposed to sun and drying influences. However, higher osmotic concentration of cells of tomato fruits late in the season, not uncommon, may be associated also with aging of vines, bringing into play the general effects of senescence.

7. Greater susceptibility of open-foliaged varieties to concentric cracking.

8. Relative severity of concentric cracking in heavy foliaged varieties, as compared to open foliaged ones, late in the season.

9. More severe cracking on pruned, staked, plants, as compared to those not pruned and not staked. In this case, not only the foliage and shading of the fruit is important, but the restricted root system of pruned plants, with its effect on internal water relations, must be considered.

Low evaporativity and continued rainfall are influential in initiating and increasing severity of cracking, yet we can not define the minimum length of time any given set of evaporative or other conditions must obtain in order for cracking to occur. Cracking would appear to be possible at any time that differential cell enlargement in any local part of the outer ovary wall tissue occurs, and this implies, as is indicated in the present data, that some cracking can proceed even during periods when evaporation is taking place.

Many of the above discussed types of tomato fruit cracking and conditions we believe to be, in varying degrees, concerned with such cracking, need further detailed analysis. Yet they should aid in partially explaining the widespread occurrence of cracking in tomato fruits, why severity varies greatly in different years, with soils, varieties, vines of a given variety, fruits on a vine, or even fruits on a cluster.

From the practical viewpoint, because of the varied role of factors previously discussed, no complete control of fruit cracking can be expected. However, the harvest of mature fruits as soon as possible, the maintenance of a constant, plentiful soil moisture supply, production of healthy, heavy foliage, and proper varietal selection offer means of partial control. Since varietal differences in cracking do occur, and since climatic factors conducive to cracking are to an important degree beyond man's control under field conditions, breeding for resistance to cracking appears logical. The senior author has had the opportunity to observe, in connection with an extensive program on tomato improvement in Hawaii, large numbers of breeding lines of simple and complex parentage, and it has been apparent that segregation for characteristic types of cracking does take place. The rather uniform climatic conditions which generally prevail in Hawaii, however, result in relatively slight cracking, so that selection for resistance under field conditions is only occasionally possible. In areas where summer droughts are common, an overhead sprinkling system, to be used for thoro, prolonged, wetting of plants and soil, following a dry period, would be advantageous to use in connection with observation of segregating progeny for resistance to cracking. In the early phases of such a breeding program, such characters as foliage cover (protection of fruit from sun), resistance to defoliation diseases, fruit shape and freedom from malformations, immature fruit skin color (dark green shoulder versus Bounty type color), fruit set, determinate growth habit, skin thickness, size of corky scar at stem end (permitting water absorption in the creases), should be observed in relation to severity and type of cracking, for these, in addition to other less easily observed vine and fruit characters, may contribute to varietal resistance or susceptibility.

SUMMARY

Fruits of some tomato varieties, such as Earliana and Grothens Red Globe, develop relatively severe concentric cracking, while others such as Marglobe and Dwarf Champion develop characteristic and relatively severe radial cracking.

Tomato fruits are particularly susceptible to cracking at a physiological age beginning a few days before reaching the pink stage and extending through the red ripe stage of development.

It appears that cracking usually takes place beyond the period of highest daily increments in growth, as calculated from circumference measurements.

High cracking indices were obtained following periods of low eva-

porativity during night hours, as compared to high evaporativity of daylight hours.

A discussion of the possible causes of various types of tomato fruit cracking is given.

It is concluded that, since varietal differences in cracking do occur, and since climatic factors conducive to cracking may often be difficult to control under field conditions, breeding for resistance is logical. A brief discussion of the breeding problem is given.

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Preliminary Report on Breeding Tomatoes for Resistance to Tobacco Mosaic Virus[1]

By K. Kikuta and W. A. Frazier, *Hawaii Agricultural Experiment Station, Honolulu, Hawaii*

Tobacco mosaic has become the most destructive disease affecting tomatoes in Hawaii. Repeated plantings of tomatoes throughout the year, on small farms, and lack of care in preventing mechanical inoculation, have resulted in widespread infection of fields even in early stages of growth. The need for tobacco mosaic resistant or tolerant varieties has, therefore, become obvious. A brief note on the program for breeding mosaic resistant types was reported by Frazier *et al.* (2). Preliminary data on the reaction of Lycopersicon species and their hybrids to inoculation with tobacco mosaic disease are reported herewith.

Sources of Tobacco Mosaic Resistance

Within recent years several Lycopersicon species and their hybrids have been reported to be resistant or highly tolerant to the tobacco mosaic virus. Holmes (3) mentioned *Lycopersicon chilense* Dun. as a possible source of mosaic resistance and he (4, 5) subsequently showed that certain derivatives from the hybrid *L. esculentum* x *L. chilense* possess a tendency, which is heritable, to escape mosaic infection. Porte *et al.* (7) reported the complete tolerance of *L. hirsutum* H. and B. to tobacco mosaic virus 1. Various strains of *L. peruvianum* have been indicated by Alexander *et al.* (1) to be a potentially valuable source of resistance to mosaic. The tolerance of a hybrid between [(*L. hirsutum* x Bonny Best) x (BC–10 x Bounty)] and *L. peruvianum* to mosaic has been observed by McFarlane *et al.* in Hawaii (6).

Strains of *Lycopersicon hirsutum, L. chilense*, and *L. peruvianum*, and several of their derivatives have been acquired from various sources, and grown for observation at the Hawaii Station. Although *L. chilenese* and *L. peruvianum* show high tolerance to mosaic, attempts to obtain hybrids with *L. esculentum* have been unsuccessful by the usual pollination method. Some *L. chilense* derivatives from J. W. Lesley of the California Agricultural Experiment Station and *L. peruvianum* derivatives from A. F. Yeager of the New Hampshire Agricultural Experiment Station seem to show some tolerance to mosaic in the field. A strain of *L. hirsutum* received from W. S. Porte of the United States Department of Agriculture as 41B107 has been growing for a year in Hawaii and plants show no mottling of foliage in the field. Several hybrids between *L. esculentum* x *L. hirsutum* or their derivatives; *L. esculentum* x *L. chilense* derivatives; *L. hirsutum* derivatives x *L. chilense* derivatives, and *L. esculentum* x (*L. hirsutum* x *L. chilense* derivatives) have been obtained at the Hawaii Station.

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[1] Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 153.

TABLE I—REACTIONS OF VARIOUS HYBRIDS AND SEGREGATING POPULATIONS TO INOCULATIONS OF TOBACCO MOSAIC VIRUS

Cross or Sel. No.	Variety or Hybrid	Generation	Total Plants	Infection Classes*				
				0	1	2	3	4
—	*Lycopersicon hirsutum*	—	5	5†	–	—	–	—
—	Pearl Harbor	—	55	–	–	—	–	55
T3256	Pearl Harbor ×*L. hirsutum*	F_1	4	–	–	—	–	4
T3401	HES-2269 ×*L. hirsutum*	F_1	13	2	–	—	–	11
T3022	PH ×(PA ×*L. hirsutum*)**	BC_1	40	–	–	—	–	40
T3293	HES-2269 × [PH ×(PA ×*hirs.*)]	BC_2	298	–	–	—	–	298
T3075	[(*L. peruv.* ×MSF) ×*L. pimp.*] ×*L. hirsutum*	Segregating	25	–	–	25†	–	—
T3075 (self)	[(*L. peruv.* ×MSF) ×*L. pimp.*] ×*L. hirsutum*	Segregating	8	4	–	1	–	3
T3400	HES-2269 × [(*L. peruv.* × MSF × *L. pimp.*) ×*L. hirs.*]	Segregating	108	5	2	17	–	84
T3399	T3074 (*L. hirs.* ×BB) ×[(PH ×*L. pimp.* ×*L. esc.* ×*L. chil.*)] × T3075 [(*L. peruv.* ×MSF) ×*L. pimp.*] × *L. hirs.*]	Segregating	64	1	1	3	1	58
HES-2650	PH ×(*L. esc.* ×*L. pimp.* ×*L. chil.*)	F_6	51	–	–	1	–	50

*Arbitrary infection classes of severity of mosaic symptoms: 0, no symptoms; 1, "flecking" or minute scattered chlorotic spots; 2, chlorotic patches or mild mottling; 3, severe chlorotic mottling; 4, chlorotic mottling and distortion.

**Key to abbreviations: PH, Pearl Harbor; PA, Pan America; *L. hirs.*, *L. hirsutum*; *L. peruv.*, *L. peruvianum*; MSF, Michigan State Forcing; *L. pimp.*, *L. pimpinellifolium*; BB, Bonny Best; *L. esc.*, *L. esculentum*; *L. chil.*, *L. chilense*.

†Ratings given from observation of symptoms due to field infections.

METHOD OF TESTING

The testing for resistance to tobacco mosaic consists mainly in mechanically inoculating seedlings approximately 20 days old with inoculum made up of juice from mosaic infected plants of tomato diluted 1:5 with water. The strain of virus used was isolated and purified by F. O. Holmes in 1946. The first symptoms generally occurred 5 days after inoculation and eliminations of infected plants were made 8 to 10 days after inoculation. It was apparent that symptoms expressed by inoculated plants varied in regard to type and severity. Pearl Harbor exhibited uniformly severe chlorotic mottling and distortion of leaves with subsequent stunting of the plants, whereas individuals from several segregating populations of hirsutum, peruvianum and chilense derivatives showed varying degrees of severity of symptoms. Arbitrary classes for differentiating the various gradations of symptoms were established with the belief that the variations in symptom expression might be a measure of resistance or tolerance. Plants showing no symptoms were given a rating of 0; those showing "flecking" or minute scattered-chlorotic spots 1; those exhibiting few chlorotic patches or mild mottling 2; those with only severe chlorotic mottling 3; and those with chlorotic mottling and distortion 4. On the basis of this classification, it was assumed that mosaic-tolerant individuals could be isolated from segregating populations if tolerance, at least in hirsutum derivatives, were indicated by degrees of severity of symptoms.

PRELIMINARY RESULTS

A hybrid, designated T3075, between [(*Lycopersicon peruvianum* x Michigan State Forcing) x *L. pimpinellifolium*] and *L. hirsutum* showed only slight mottling under field conditions, whereas Pearl Harbor plants adjacent to it showed severe chlorotic mottling and distortion of leaves. A lot of *L. hirsutum* plants (Porte, 41B107) remained symptomless. The excellent vigor and growth (30 to 35 feet in circumference), and the apparent tolerance (only mild mottling) to mosaic of the hybrid were sufficient to continue further hybridization. This complex hybrid, used as a male parent, was crossed to HES–2269, an esculentum type HES–2214 derivative bred for combined resistance and described by Frazier *et al.* (2). The resulting hybrid, designated as T3400, was tested for resistance to tobacco mosaic disease. Reaction of the progeny to inoculation varied. Several segregates with seemingly high tolerance emerged from the cross. From a lot of 108 seedlings, when inoculated with tobacco mosaic virus, 20 showed no chlorotic mottling (class 0); 14 "flecking" (class 1); 12 flecking or mottling (class 2); 18 severe mottling (class 3); and 44 severe mottling and leaf distortion (class 4). Plants rated in classes 3 and 4 were eliminated. Plants in classes 0, 1 and 2 were reinoculated and those showing symptoms of classes 3 and 4 magnitude were discarded. After the second inoculation (see Table I) of the original 20 showing no mottling, 5 remained symptomless, but 15 showed sufficient severity of symptoms to be rated in class 2. Of the 14 in class 1, 12 plants were discarded and of the 12 in class 2, 10 were eliminated. Thus, 22 additional eliminations from the second inoculation left 5 plants in class 0, 2 plants in class 1, and 17 in class 2 from a total of 108 seedlings. These remaining seedlings were transplanted to the field for further

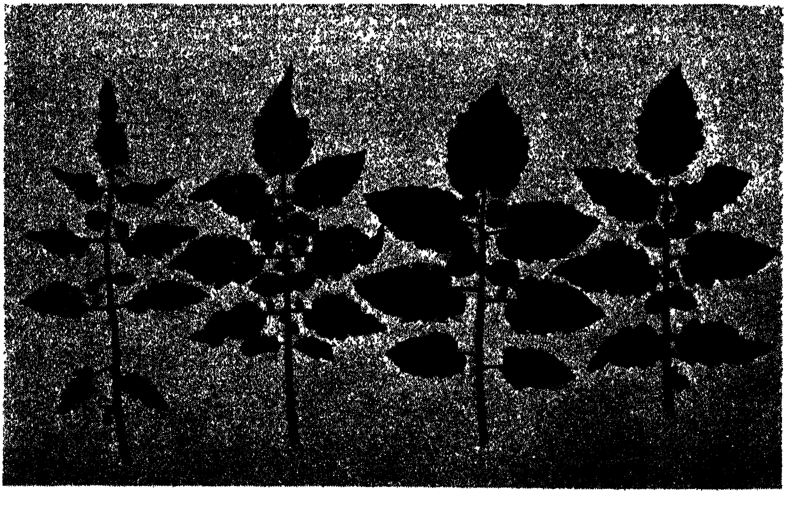

FIG. 1. Tolerance to tobacco mosaic virus in tomato. Left, leaf from susceptible Pearl Harbor; left center, susceptible segregate from F_1 hybrid of T3400 *Lycopersicon esculentum* (HES–2269) x [(*L. peruvianum*-Michigan State Forcing x *L. pimpinellifolium*) x *L. hirsutum*]; right center, a tolerant segregate from T3400; and right, tolerant F_1 hybrid T3075, one of the parents of hybrid T3400.

observation. However, the five symptomless segregates did not remain symptom free. Approximately 3 weeks later, three of the five developed moderately severe mottling, and two developed only faint mottling not unlike that of the male parent T3075. Several other segregates originally rated in classes 1 and 2 remained vigorous and showed only faint mottling or flecking, and a few severe mottling and distortion with stunting. In general, the apparently tolerant segregates set very few fruits; however, a single segregate rated in class 2 set numerous yellow fruits ¾ inch in diameter.

At present, it is hardly to be expected that hybrids with the symptomless condition of *Lycopersicon hirsutum* are obtainable, but the possibility exists that some individuals with tolerance or resistance that would approximate that possessed by the complex hybrid T3075 can be obtained.

Due to very light fruit set in the hybrid T3075 [*(Lycopersicon peruvianum* x Michigan State Forcing) x *L. pimpinellifolium*] x *L. hirsutum*, only a few seeds for an F_2 population were available. Of the eight seedlings, four remained symptomless and three were severely infected. One was rated in class 2. The four symptomless segregates remained highly tolerant to mosaic when planted in the field.

All four F_1 plants of Pearl Harbor x *Lycopersicon hirsutum* were eliminated after the first inoculation due to severe mosaic symptoms. Two out of 13 plants of 2269 x *L. hirsutum* remained free of symptoms after receiving two inoculations. However, when these two symptomless plants were transplanted to the field they developed severe symptoms of mosaic after a month's growth. It seems that seedlings remaining symptomless even after two heavy inoculations cannot be assumed to remain free of symptoms in later stages of their growth.

It is interesting to note that these F_1 *Lycopersicon esculentum* x *L. hirsutum* crosses, when flowering is about to begin, develop severe yellowing followed by necrosis and subsequent dropping off of the affected lower leaves. This characteristic, apparently of a genetic nature, has not been observed in the hybrid T3075 [*(L. peruvianum* x Michigan State Forcing) x *L. pimpinellifolium*] x *L. hirsutum* but only in strictly *L. esculentum* x *L. hirsutum* crosses and in a few segregates of the hybrid T3400 *L. esculentum* x T3075. The plants lack vigor, produce few flowers and no fruit. As yet no F_2 seeds have been obtained from an *L. esculentum* x *L. hirsutum* cross in Hawaii.

Inoculation with tobacco mosaic of 40 plants of a first backcross (T3022) of *Lycopersicon esculentum* (Pan America) x *L. hirsutum* to *L. esculentum* (Pearl Harbor) gave uniform response in every individual by showing severe chlorotic mottling. All 298 individuals from a second backcross (T3293) to esculentum also showed uniformly severe infection.

A hybrid T3074 *(Lycopersicon hirsutum* x Bonny Best) x [Pearl Harbor x *(L. pimpinellifolium* x *L. esculentum* x *L. chilense)*] has been crossed to the complex hybrid T3075 [*(L. peruvianum* x Michigan State Forcing) x *L. pimpinellifolium*] x *L. hirsutum*. The resulting complex hybrid T3399 has been tested for resistance to tobacco mosaic virus, and of the 64 plants, 7 showed no mosaic symptoms while 55 showed severe mottling and distortion. The other two plants showed intermediate symptoms. After a second inoculation only one plant showed no symptoms. When transplanted to the field along with five others showing only mottling or chlorotic patches on older leaflets, the single symptomless plant, although very vigorous, developed severe mottling. However, a segregate originally rated in class 2 has remained highly tolerant and vigorous.

At present, six individual segregates from the hybrid T3400 between [(*Lycopersicon peruvianum* x Michigan State Forcing) x *L. pimpinellifolium*] x *L. hirsutum* and *L. esculentum* (HES–2269) apparently possess sufficiently high tolerance to tobacco mosaic for practical value and further hybridization. It is apparent that the symptomless tolerance possessed by *L. hirsutum* is not completely dominant as evidenced by the reaction of the F_1 crosses. Since no F_1 *L. esculentum* x *L. hirsutum* has shown any practical degree of tolerance and since the complex hybrid T3075 involving *L. peruvianum, L. pimpinellifolium* and *L. hirsutum* exhibited considerable tolerance, it is highly probable that *L. peruvianum* and *L. pimpinellifolium* derivatives or their combination with *L. hirsutum* germplasm have contributed to the tolerant nature of the segregates. This probability is also suggested by the high initial percentage of mosaic tolerant segregates from the self of the complex species cross T3075 and their vigorous appearance in the field.

A single F_2 segregate from T3075 appears to possess a higher degree of tolerance to mosaic than the F_1, but to what extent after

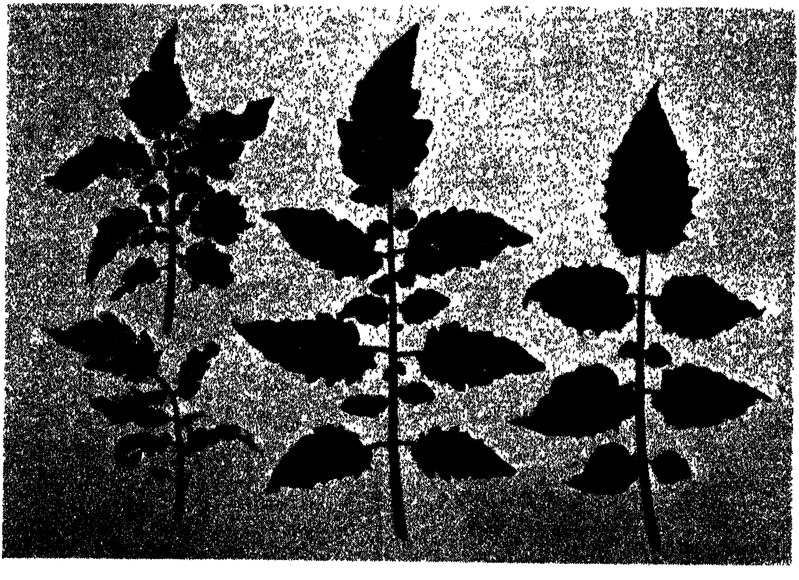

FIG. 2. Left above, a highly susceptible segregate from T3400; left below, Pearl Harbor; center, a mosaic tolerant segregate from T3400; and right, a highly tolerant segregate from F_3 population of T3075.

crossing to *Lycopersicon esculentum* it will retain this tolerance must await further investigation.

Response to inoculations with tobacco mosaic indicates that hybrids involving *L. hirsutum* and *chilense* derivatives have not been as tolerant as those involving *L. peruvianum, pimpinellifolium* and *hirsutum* derivatives. In certain *L. chilense* derivatives vein-clearing symptoms of high severity as well as severe chlorotic mottling have been observed. A wide range of symptoms from pin-point flecking through mild mottling to severe mottling and distortion of leaves has been found in populations of *L. hirsutum* derivatives. However, symptoms expressed by plants during certain stages of their growth may not be absolute criteria of their tolerance to or susceptibility to mosaic in other stages. Individuals showing the symptomless condition in their young stages of growth have been observed to develop severe symptoms in later growth, whereas in some cases seedlings exhibiting moderately severe infections seem to develop milder symptoms with vigorous growth of vines. In general, however, it seems that the higher the resistance or tolerance in the seedling stage the higher the tolerance of the plant in later stages.

It is recognized that many questions remain unanswered at this stage of the program in breeding for mosaic resistance. Differences not noticeable in individual *Lycopersicon hirsutum* plants used in making certain of the F_1 hybrids may have been important factors in the type of symptoms shown by several crosses inoculated with tobacco mosaic virus. Chance inoculations with different strains of tobacco mosaic virus, or even with the cucumber mosaic virus may be complicating the picture with respect to field behavior of plants in late stages of growth. Although these, as well as other factors, have not been clarified, it is, nevertheless, encouraging to observe the tolerance exhibited in certain of the individual plants now growing in the field.

SUMMARY

The testing of several tomato hybrids for resistance or tolerance to tobacco mosaic disease and the wide range of symptoms expressed by inoculated plants from segregating populations are described.

The apparently symptomless condition of *Lycopersicon hirsutum* is not completely dominant in F_1 hybrids of *L. esculentum* x *L. hirsutum.*

Several segregates from a cross of *Lycopersicon esculentum* (HES-2269) x [*(L. peruvianum* x Michigan State Forcing x *L. pimpinellifolium)* x *L. hirsutum*] showing high degrees of tolerance to mosaic have been obtained.

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Effects of Skim Milk on the Growth and Yields of Tomatoes (Preliminary Report)[1]

By V. E. IVERSON, *Montana Agricultural Experiment Station, Bozeman, Mont.*

THE chemical analysis of milk (1) indicated that it might have some value as a fertilizer for horticultural plants. In 1946 exploratory experiments were conducted by the Department of Horticulture of the Montana Agricultural Experiment Station, to determine the effects of soil applications of skim milk upon the growth of Bonny Best tomato plants.

Preliminary tests consisted of a total of four treated and four untreated plots. Out of 32 plants per treatment, 16 were grown to maturity in the greenhouse and 16 were transplanted into the field in two replications of eight plants per treatment.

The treatments consisted of applying a total of 150 cubic centimeters of skim milk per plant over a period of 5 weeks; applying 10 cubic centimeters the first week, 20 cubic centimeters the second, 30 cubic centimeters the third, 40 cubic centimeters the fourth and 50 cubic centimeters the fifth week. The skim milk was applied directly upon the soil in which the transplants were growing. The soil mixture consisted of 25 per cent well-rotted manure, 25 per cent sand, and 50 per cent loam. The first application of skim milk was made when the plants were about 2 inches high. After each application, all of the plants were thoroughly watered to allow for maximum distribution of the skim milk in the soil.

The skim milk treatment was found to produce the following results in both the greenhouse and field-grown plants:

1. Larger, more fibrous root systems.
2. Larger stems and taller plants with greater leaf areas. (Treated plants averaged 1.6 inches taller than checks when 55 days old).
3. Increased early and total yields. (Treatment resulted in an average increase of 40 per cent in early yields and 49 per cent in total yields. The minimum per cent increase for any plot was 26 per cent for early and 27 per cent for total yields).

Due to the size and limited scope of this experiment, it must be considered exploratory in nature. More supporting data is needed before this treatment can be recommended for general use. At the present time, more extensive tests are under way to determine the best time and rate of application of skim milk and related substances, including powdered buttermilk, powdered skim milk, and whey upon a variety of horticultural plants. It is also anticipated that chemical and biological tests will be made to determine the nature of the effects of these substances upon plant growth.

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[1] Journal Paper No. 183, Montana Agricultural Experiment Station.

Influence of the Length and Manner of Storage of Tomato Seedlings on Stand, Early Growth, and Yield[1]

By H. Rex Thomas and W. D. Moore, *U. S. Department of Agriculture, Beltsville, Md.*

Tomato seedlings grown in the Southern States and shipped to the Northern canning growers for transplanting frequently arrive during weather unfavorable for immediate setting. Growers are forced to either store the plants or discard them and await a new shipment. Such a decision is based on the prospects of disease development and the influence of storage on the subsequent growth and yield of the plants. Moore and Thomas (1) have shown that the infection of tomato seedlings by *Alternaria solani* increases as the period of storage is lengthened. During seasons when the disease incidence is low in the plant-growing areas, plants relatively free of inoculum can probably be stored without appreciable disease development. The present studies were concerned with the influence of the storage upon stand, early growth, and yield.

During the 1942 season four lots of tomato seedlings of the Indiana Baltimore variety, were pulled at 2-day intervals at Tifton, Georgia, and shipped to Lafayette, Indiana. The seedlings were packed in bundles of 25, eight bundles in each 5/8 bushel hamper. Moist peat moss was applied around the roots at time of packing. Two hampers were sent in each shipment. Upon receipt in Indiana the peat moss in one hamper was kept moist by dipping the hamper into a container filled with 3 inches of water for a 5- to 10- minute period daily. All lots were stored in a dry room at approximately 70 degrees F. When the fourth shipment arrived, all of the plants from the different shipments were set in the field. The first three shipments were 2 days enroute and the last one 3 days.

There were seven groups of plants: (1) plants held 7 days not moistened, (2) held 7 days moistened, (3) held 5 days not moistened, (4) held 5 days moistened, (5) held 3 days not moistened, (6) held 3 days moistened, and (7) plants set immediately upon receipt.

Each plot consisted of 12 plants, set 3½ feet by 3½ feet, in two rows of 6 plants each. There were seven replicates, arranged in a latin square. The plants were set on May 23, at which time the soil was in a good moist condition. A trace of rain was recorded on May 24, 25, 27, June 1, 3, and 4. At the time of setting ¼ pint of "starter" solution (20 ounces ammophos, 10 ounces nitrate of potash, 50 gallons of water) was added. Extra plants of each treatment were heeled in for resetting after stand counts were made 7 days later. The stand, average number of leaves per plant 7 and 16 days after setting, and early, mid-season, and final yield records are presented in Table I. The yield data

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[1] Conducted as a phase of cooperative investigations between the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture and the Department of Botany, and Plant Pathology, Purdue University Agricultural Experiment Station; New Jersey Agricultural Experiment Station; Georgia Coastal Plain Experiment Station; Georgia Agricultural Experiment Station, and the Georgia State Department of Entomology.

TABLE I—Influence of the Length and Manner of Storage of Tomato Seedlings on Stand, Early Growth, and Yield

Length and Manner of Storage (Plants 2 Days in Transit Before Storage)	Average Stand 7 Days After Setting* (Per Cent)	Average Number of Leaves Per Plant 7 Days After Setting	Average Number of Leaves Per Plant 16 Days After Setting	Average Yield Per Acre (Tons)		
				Early Season, to Aug 18	Mid-season, to Sep 9	Total, to Sep 28
7 days—peat moss not moistened	76.7	1.4	6.7	3.8	10.7	19.4
7 days—peat moss moistened** .	84.2	2.3	8.1	4.5	12.4	21.5
5 days—peat moss not moistened	78.0	2.4	8.0	4.6	11.5	19.1
5 days—peat moss moistened ...	84.5	3.4	9.4	5.5	12.6	19.4
3 days—peat moss not moistened	96.4	3.8	9.4	6.3	13.2	20.2
3 days—peat moss moistened....	98.2	4.0	9.9	6.7	14.5	21.7
Set immediately‡..............	95.4	4.3	9.9	5.8	12.8	20.0
Difference required for significance 5 per cent level..............	3.8	.4	1.0	1.2	1.7	—†

* Average of seven plots of 12 plants each—plants set May 23, 1942.

**Peat moss kept moist by dipping hamper for 5 minutes every other day in a tub filled with 3 inches of water.

†F value for experiment not significant.

‡Plants 3 days in transit before storage.

includes fruit from the reset plants. Pickings were made July 28, August 3, 10, 18, 26, September 4, 15, 28. The first four pickings were combined for the early yield and the first six for the mid-season figure.

A significant reduction in stand occurred in the shipments held in Indiana for 5 and 7 days, either moistened or non-moistened, when compared with those set immediately and those held for 3 days, either moistened or non-moistened. In every case the plants from the moistened group had a better stand than those not moistened.

Plants held longer than 5 days had significantly fewer leaves 7 days after setting than those held for 3 days or set immediately. The plants from the moistened series had more leaves than any of the corresponding plants kept dry. Only in the case of the plants held 5 days or longer was this difference statistically significant.

Sixteen days after setting there were no significant differences between the moistened plants held 5 days and either of the groups held 3 days or those set immediately. Those held 5 days without moistening and both groups held 7 days had significantly fewer leaves than the above group. The plants in the moistened lots had more leaves than the unmoistened plants.

The early yield of the two lots held 7 days and the 5-day non-moistened plants was significantly less than that of the other plants. Again the moistened group was always better than the non-moistened group. At mid-season the largest yield was obtained from the moistened plants held 3 days. This yield was significantly better than that of the plants set immediately. Compared with the plants set immediately only the non-moistened plants held for 7 days had a significantly smaller mid-season yield. The yield from the moistened plants was better than that of the non-moistened plants at each period of storage.

There were no significant differences in total yield between treatments but, as in the earlier yields, there was a slight increase in yield of the moistened over the non-moistened plants.

Although all shipments arrived without evident injury, it is recognized that conditions in transit may have varied somewhat among the shipments and that this factor might have had some effect on the performance of the plants in the field.

SUMMARY

The results obtained in 1942 showed that the stand, early growth as measured by number of leaves per plant, and early yield of those plants held longer than 3 days were significantly reduced when compared with those plants held for 3 days or set immediately. In total yields there were no significant differences between treatments.

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Studies of Tomato Diseases in the Amazon Basin of Peru (Preliminary Report)

By Bowen S. Crandall and Charles F. Swingle, *U. S. Department of Agriculture, Office of Foreign Agricultural Relations, Estacion Experimental Agricola, Tingo Maria, Peru*

The establishment of the Estacion Experimental Agricola at Tingo Maria jointly by the Ministry of Agriculture of Peru and the United States Department of Agriculture was based largely on the need for rubber, cinchona, and rotenone exported in quantity from Peru to the United States. However, a very important prerequisite for the success of the Station in stimulating such complementary crops in Eastern Peru is that the inhabitants in this area of some 150 inches of rainfall have something to eat. Hence, a large part of our work at Tingo Maria has been with dairy and beef cattle, corn, beans, rice, and other foods crops. It must be borne in mind that until very recently this vast area had produced hardly anything except lumber, and that our work is not a simple matter of improving any crude though effective existing agriculture, but rather of building almost completely from the ground up.

At first, it was felt that tomatoes could be produced without difficulty in this country which abounds in native Solanaceae and which might well be the real home of the tomato. More or less success was obtained with Yellow Queen, Marglobe, John Baer, Globelle, Rutgers, and a few other United States varieties, fairly good crops of large well formed fruits being obtained on several occasions. However, we did not seem to be able to repeat these successes, for frequently we lost many of our plants.

The end of September 1945 we woke up to the fact that we had a full scale epidemic of *Cladosporium fulvum* Cke. leaf-mold. In checking back it was apparent that the same sudden damage had occurred in 1944 at about the same time, which coincides with the onset of the wet season. Since it was rather difficult to give our field tomatoes more ventilation, as the instructions for control of leafmold advise, and since we can hardly hope for tomato production here among the low income farmers, if any elaborate spray program is required, we felt that the only out for us was to find or develop a resistant strain.

This is why during the past year we asked many of you for help in our problem. We certainly got a wonderful response from the United States tomato breeders, and are happy to advise you that this was really of great help to us, and feel it will also prove of direct aid to those of you who have assisted us.

The seeds sent us throughout 1946, as well as the best of our own seeds, were planted as fast as obtained, and with conscious effort to subject the plants to leafmold inducing conditions. Thus, by the end of September 1946 we had a large population of tomatoes, at all stages from germinating seedlings to plants in full production, the latter from twice selected seeds. As in 1944 and 1945, leafmold came in again the last of September with the onset of the wet season. Most of the full grown plants were killed outright or very severely injured, as happened the two preceding years. But a few stood out conspicuously. These were Bay State Improved (the best); Mold Resistant Waltham Forcing; Ohio Globelle; Improved Vetomold 121; Vetomold 121; Vetomold from Ontario; our own Marglobe, John Baer and Rutgers. The Turrialba tomato, developed by Mr. Joseph Finnell at Turrialba, Costa Rica, was received at Tingo Maria too late to include in the main tests. However, we have every reason to believe it will be placed among the very resistant varieties.

In addition to the varieties listed above, a Globelle type selection from the Louisiana station also seems to be very promising, but we have not yet had sufficient plants to include it in our regular tests.

The following varieties showed no resistant individuals at all, and are being completely eliminated from further consideration as varieties for our region: Yellow Queen, Globelle, Chatham, Break-of-Day, Stokesdale, Bay State.

It is certainly an outstanding instance of the internationality of science when we find the tomatoes bred in Ontario, Ohio, and Massachusetts for greenhouse use, turning out to be best for field conditions in the Amazon basin. Similarly, we feel that this is not going to be all one way cooperation, for under our conditions at Tingo Maria, we are in position to give prompt and almost continuous test to any tomatoes supposedly leafmold resistant. Furthermore, we think that one or more generations at Tingo Maria will subject tomatoes to more strains of leafmold than are apt to be present at any one station in the United States or Canada. We have already sent some materials back to the stations from which they came, as well as some of our wild tomato relatives; we are in position to return more of both classes of materials. Naturally, we are giving first choice to those stations which have provided us with seeds, but we feel for the experimental lots involved we can probably take care of all requests.

We have subjected our experimental plants to planting on old land, crowding, and other conditions conducive to high incidence of disease in the hope of speeding up the selection process. Under normal farm conditions at Tingo Maria, with relatively small plantings for home use only, far removed from any concentrations of cultivated tomatoes, we feel we already have sufficient resistance to leafmold at our disposal to make tomato growing feasible. We shall have the answer to this shortly, as we have already distributed considerable quantities of our fairly resistant types.

We realize the non-static nature of such programs, and mean to continue our selections in the hope of keeping ahead of any possible build-up of virulence. Also, of course, we have no reason to feel that other diseases will not strike. In fact, one of these is already in our region and apparently also is widespread in Peru and Bolivia, a virus characterized by purpling and uprolling of leaves. This caused considerable loss to us a year ago at the start of our leafmold breeding program, so we feel we probably also have a considerable degree of virus resistance into the selections picked out as resistant to leafmold. Here again, we can not be too sure.

We have mentioned the wild Solanums in our midst. Did Cladosporium (and perhaps virus) originate here on these wild types? Frankly, we do not know. The semiwild tomatillo which we have here, with fruit about an inch in diameter, is definitely attacked by both Cladosporium and virus, showing in some cases less resistance than the selections named above. Since the leafmold rarely kills the plants outright, this could mean that these diseases had been here a long time and the tomatillo had worked out a live and let live arrangement with the Cladosporium, without developing complete resistance. Or we could have a recent introduction.

It is planned to publish the full results of these tests in the near future. In view of the results obtained thus far, however, it seemed to us only fair that we give this partial report at this time to let you, who have had such a hand in the work, know what was happening.

The Effect of Certain Planting and Harvest Dates on the Quality of Table Beets

By O. A. LORENZ, *University of California, Davis, Cal.*

UNDER the climatic conditions of Central California it is possible to grow beets for an entire year before harvesting. This practice has often resulted in the poor quality of canning beets. The study reported here was made to determine the effect of season of growth and length of growing period on the quality of canning beets.

METHODS

Four strains of table beets were planted at the University Farm at Davis on three different dates and then sampled at several different stages of growth. The strains used were Improved Detroit Dark Red, Crosby Egyptian, Good for All, and Detroit Dark Red. The first three were obtained from the Ferry-Morse Seed Company and the latter from the Corneli Seed Company. Plantings were made in the field on a Yolo fine sandy loam soil on May 30, 1944, September 16, 1944, and February 16, 1945. The plants were grown in double rows on raised beds spaced 3 feet from center to center. Irrigation water was applied at fairly regular intervals during the summer months, which was usually every 10 to 14 days. The first samples were taken when the beets were from 1 to 2 inches in diameter. Sampling was then continued at infrequent intervals until the beets had overwintered and showed definite signs of seedstalk development, which was in March of the year following planting. At each sampling date 50 random beets of each strain were harvested and the fresh weight of both tops and roots recorded. The exact dates of harvest are shown in Tables I, II, and III. Notes were made on general quality factors such as taste and internal color. Internal color was rated from 1 to 10 with the higher number indicating the darkest and most uniform color. The colored plates (plate 30, Misc. Pub. 374) (2) as published by the United States Department of Agriculture were used as a basis for the color ratings. Duplicate samples of each lot were preserved for chemical analysis. Reducing sugars were determined by the Quisumbing-Thomas method (1). Sucrose was inverted with malt invertase at 30 degrees C for 18 hours, after which the samples were treated as for reducing sugars. Alcohol insoluble material was designated as that fraction insoluble in boiling 80 per cent alcohol. Betanin was determined on all samples by the method of Pucher, Curtis, and Vichery (3) but as the results varied greatly from the visual color the data are not reported. The differences may have been caused by partial carmelization of the tissues in the process of drying.

RESULTS

Beets from the planting of May 30, 1944 reached first canning size by July 21. At this time the color was fair and most beets showed moderately few white zones except in the Crosby Egyptian where the color was light throughout and white zoning fairly prominent. By

August 28 color of the Crosby Egyptian had improved but the other varieties remained about the same. Maximum red color was evident in the samples harvested in December and again in March. By these dates white zones were very indistinct except in Crosby Egyptian. Also by December many beets showed bronze color at the center, which continued to develop through the March sampling. Bronzing may be defined as the metalic brown color imparted to both tissue and juice. The tops practically died after the October sampling and many beets were starting a new flush of growth. When sampled on March 28 many beets of all strains were pithy, cracked at the center, and totally unfit for manufacture, however the strain of Good for All was decidedly the poorest. After March all strains formed seed stalks and were not sampled further.

From the planting of September 16, 1944 only two samplings were made; January 30, 1945 and March 30, 1945. At the first date the beets averaged about 1½ inches in diameter, an ideal size for canning whole. The tops of the plants were of blood red color due to the cool weather and the color of the roots was very dark. White zones were indistinct except for a few roots of Crosby Egyptian. Beets from these lots were probably the darkest of any that were found at any growing period. On March 30 the beets were still of small size, but white zones were prominent in all strains and especially so in Crosby Egyptian and Good for All. At the time practically all beets had started a new flush of top growth and seedstalks were plainly visible.

From the planting of February 16, 1945, samples were taken on May 20, July 13, and November 7, 1945 and on March 5, 1946. Beets at the first sampling averaged slightly over 2 inches in diameter. They were of fair color but white zones were clearly visible in all. By July 13 all large beets showed distinct white zones and by November 7 the beets were unfit for canning. Bronzing was severe in a good many of the beets, and some of the larger beets were quite pithy. On March 5 th visual quality had further deteriorated. White zones were more distinct, and pithiness and bronzing had further increased.

Growth and chemical data for the beets of the May 30, 1944 planting are presented in Table I. The beets increased greatly in growth between July 21 and August 28 but made only little growth after the latter date. Total dry matter was highest in samples harvested on August 28 or October 4. Both strains of Detroit Dark Red showed the lowest dry matter in samples harvested on March 30. Alcohol insoluble solids remained fairly constant at all dates of sampling. Total sugars increased appreciably in the samples taken on August 28 or October 4 as compared to those of July 21, and then decreased markedly in samples of December 28 and March 30. On both of these latter dates the beets were unfit for canning. Sucrose changed in very much the same manner as did total sugars. Invert sugars were practically nil in the early samples but increased and reached the highest amount in the March samples.

Beets planted on September 16 showed little difference in chemical content between samples harvested on January 30 and March 30 (Table II). Alcohol insoluble solids decreased slightly between the

TABLE I—COMPOSITION AND COLOR OF CERTAIN VARIETIES OF TABLE BEETS AT DIFFERENT DATES OF SAMPLING (PLANTING OF MAY 30, 1944)

Sampling Date	Average Weight Per Root (Gms)	Percentage of Fresh Weight					Color Rating 1-Poor 10-Excellent
		Dry Matter	Alcohol Insoluble Solids	Invert Sugar	Sucrose	Total Sugars	
			Improved Detroit Dark Red				
Jul 21, 1944	21	13.75	5.28	0.14	6.77	6.91	7
Aug 28, 1944	90	15.12	4.84	0.34	7.49	7.83	8
Oct 4, 1944	116	14.88	4.87	0.66	7.10	7.76	8
Dec 28, 1944	132	12.68	5.13	0.78	3.99	4.76	8
Mar 30, 1945	113	10.91	5.71	1.10	2.15	3.25	8
			Crosby Egyptian				
Jul 21, 1944	28	11.16	4.50	0.13	5.99	6.12	2
Aug 28, 1944	168	12.06	3.58	0.35	7.03	7.38	8
Oct 4, 1944	182	13.44	4.10	0.73	8.15	8.88	8
Dec 28, 1944	176	12.62	4.10	0.73	5.51	6.24	8
Mar 30, 1945	149	12.52	4.62	1.53	4.48	6.01	10
			Good For All				
Jul 21, 1944	18	13.53	5.66	0.10	6.36	6.46	5
Aug 28, 1944	104	12.07	5.07	0.93	7.22	8.15	4
Oct 4, 1944	106	15.10	5.00	0.34	8.15	8.49	5
Dec 28, 1944	116	13.98	5.12	0.31	6.32	6.63	6
Mar 30, 1945	114	12.54	5.18	1.08	2.90	3.97	6
			Detroit Dark Red				
Jul 21, 1944	29	12.71	4.84	0.08	6.60	6.68	4
Aug 28, 1944	216	13.22	4.16	0.39	7.76	8.15	2
Oct 4, 1944	202	14.86	4 74	0.35	8.16	8.51	7
Dec 28, 1944	227	13.78	4.80	0.21	6.67	6 88	9
Mar 30, 1945	262	11 41	4.52	0.85	5.12	5 97	8

TABLE II—COMPOSITION AND COLOR OF CERTAIN VARIETIES OF TABLE BEETS AT DIFFERENT DATES OF SAMPLING (PLANTING OF SEPTEMBER 16, 1944)

Sampling Date	Average Weight Per Root (Gms)	Percentage of Fresh Weight					Color Rating 1–Poor 10–Excellent
		Dry Matter	Alcohol Insoluble Solids	Invert Sugar	Sucrose	Total Sugars	
			Improved Detroit Dark Red				
Jan 30, 1945	41	14.36	5.46	0.07	5.80	5.87	10
Mar 30, 1945	54	14.49	5.10	0.09	7.00	7.09	4
			Crosby Egyptian				
Jan 30, 1945	29	14.20	5.20	0.04	6.22	6.26	7
Mar 30, 1945	52	11.32	4.14	0.03	5.06	5.09	4
			Good For All				
Jan 30, 1945	22	15.40	6.44	0.05	6.94	6.99	10
Mar 30, 1945	39	15.00	5.28	0.03	7.59	7.62	2
			Detroit Dark Red				
Jan 30, 1945	41	14.16	5.43	0.04	7.50	7.54	10
Mar 30, 1945	66	14.64	4.86	0.04	7.48	7.52	6

two samplings. It is worth noting that beets of the first sampling were very dark in color throughout and of excellent quality while those of the latter sampling showed distinct white zones and some bronzing, yet beets from the two samplings showed almost identical sugar content.

Table III gives data for the planting of February 16, 1945. Growth was rapid between May 28 and July 18, however there was little or no increase after November 7. Sucrose and total sugars behaved much the same as for the planting of May 30, 1944. During the early stages of growth and continuing throughout the summer, sucrose and total sugars remained practically constant and then decreased greatly by November. They further decreased until March when sampling was discontinued. Total dry matter showed changes similar to those of total sugars, however, alcohol insoluble solids and invert sugar remained fairly constant at all stages of harvest. Invert sugars were very low at all sampling dates.

TABLE III—COMPOSITION AND COLOR OF CERTAIN VARIETIES OF TABLE BEETS AT DIFFERENT DATES OF SAMPLING (PLANTING OF FEBRUARY 16, 1945)

Sampling Date	Average Weight Per Root (Gms)	Percentage of Fresh Weight					Color Rating 1–Poor 10–Excellent
		Dry Matter	Alcohol Insoluble Solids	Invert Sugar	Sucrose	Total Sugars	
Improved Detroit Dark Red							
May 28, 1945	66	10.95	4.16	0.09	6.38	6.47	9
Jul 13, 1945	162	11.23	3.62	0.44	5.09	5.53	7
Nov 7, 1945	315	8.14	3.46	0.14	1.86	2.00	6
Mar 5, 1946	285	6.54	4.11	0.10	1.87	1.97	7
Crosby Egyptian							
May 28, 1945	51	9.52	3.70	0.06	6.62	6.68	5
Jul 13, 1945	151	10.01	3.23	0.41	4.94	5.35	4
Nov 7, 1945	388	8.08	3.77	0.11	2.08	2.19	7
Mar 5, 1946	321	6.33	3.74	0.15	1.68	1.83	5
Good For All							
May 28, 1945	72	11.06	4.68	0.05	6.50	6.55	5
Jul 13, 1945	271	10.82	3.30	0.23	5.02	5.25	1
Nov 7, 1945	346	8.18	4.30	0.11	1.86	1.97	3
Mar 5, 1946	316	6.38	4.26	0.18	1.65	1.83	4
Detroit Dark Red							
May 28, 1945	56	12.22	4.54	0.09	7.57	7.66	4
Jul 13, 1945	210	11.88	3.46	0.20	6.55	6.75	5
Nov 7, 1945	341	8.11	3.46	0.13	2.14	2.27	4
Mar 5, 1946	423	5.26	3.52	0.06	1.16	1.22	3

DISCUSSION

The results reported show no direct or consistent association between the sugar content and good internal color of table beets. In many cases beets of very poor color harvested at one period were higher in sugars than those of good internal color harvested at another. In some cases beets that were totally unfit for canning either because of poor internal color or pithiness were often as high in sugars as those of good internal quality. On the other hand, beets of exceptionally low sugar content were always of poor quality and totally unfit for canning. In very old spring-planted beets the development of seedstalks after overwintering was definitely associated with depletion of sugars in the root but in the one crop of young fall-planted beets even when seedstalks were plainly visible the next spring there was no depletion of sugars in the beet. Season also plays an important part in determining quality since the planting during the summer of 1944 averaged considerably higher in sugars and dry matter than the planting of 1945.

SUMMARY

Growth, internal color, dry matter, and sugars were followed in four strains of table beets planted at three different times. Beets planted in February were of high sugar content and good general quality until July, after which sugars decreased and color became poorer. Beets of a May planting remained of fair quality and high sugar content as late as October. Beets planted in September approached first canning size and were of excellent quality by November. By March of the year following, beets from all plantings had produced seedstalks.

Good internal color was not directly related to high sugar content of the beets, however, beets of very low sugar content were always of poor canning quality. Changes in sucrose were closely paralleled by changes in total dry matter. In old beets seedstalk formation was associated with depletion of sugars in the root.

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Fertilizing 456 Lettuce on Muck Soils[1]

By G. J. RALEIGH, J. F. HARRINGTON, R. KUNKEL, and
W. E. CHAPPELL, *Cornell University, Ithaca, N. Y.*

KNOTT, Anderson and Sweet (1) found that high nitrogen fertilizers increased the amount of tipburn in Imperial 44 lettuce. Because 456 is much more resistant to tipburn than Imperial 44 it was thought desirable to run similar experiments using the newer variety.

During 1941, 1942, 1943 and 1945 tests were made on deep woody muck soils in Oswego County and in the Genesee-Orleans County area. Three fertilizer analyses, (0–10–5, 2½–10–5, 5–10–5) were used at the rate of 800 pounds to the acre. In most experiments the treatments were replicated four times. The fertilizer was applied by hand on plots 1 rod by 2 rods in size and disced into the soil. The lettuce was grown from seed sown soon after the land was fitted and the plants were later blocked to stand at intervals of 15 inches in rows 15 inches apart. The years 1943 and 1945 were characterized by wet cold springs.

RESULTS

In 1941, two experiments were seeded June 4 and harvested on July 25 and July 28. There were no significant differences in either experiment. One experiment seeded May 26, 1942 and harvested July 27 showed no consistent difference due to treatment. One replication without nitrogen was very immature at the date of harvest. In the other experiment seeded June 9, 1942 and harvested August 14 there were no significant differences in yield from the various fertilizers but the lettuce from the high nitrogen plots was over mature and there was considerable rib cracking. It was also more tipburned than the lettuce from the plots without nitrogen. Lettuce from the latter plots was at good cutting stage. There were some immature plants in those plots.

An experiment seeded on May 7, 1943 and harvested July 19 responded markedly to nitrogen. On the plots lacking nitrogen, there was no marketable lettuce at the harvesting date. Lack of nitrogen had delayed the growths of the plants sufficiently that none had formed marketable heads.

In another experiment seeded May 25, 1943 and harvested July 24, there was some reduction in yields in the plots without nitrogen but results were inconclusive due to the amount of aster yellows in all plots.

Results from plots seeded May 3, 1945 and harvested on July 17 were very similar to those of the early planted experiment of 1943. There were no marketable heads in plots without nitrogen. Later a few small, very hard heads were cut from those plots.

DISCUSSION

The two experiments with relatively early lettuce during the wet years of 1943 and 1945 showed marked response to nitrogen. In nearly all of the experiments, nitrogen tended to hasten the maturity of the plants, due probably to the deficiency of nitrogen in the early stages of growth of the plants without nitrogen.

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[1] Paper No. 284. Department of Vegetable Crops, Cornell University, Ithaca, New York.

There was very little tipburn in any experiment. Where there was an increase in the amount of tipburn in the plots receiving the maximum quantity of nitrogen the burn is thought to have been due to the overmature condition of the plants at time of harvest.

It is suggested that complete fertilizer supplying 40 or 50 pounds of nitrogen to the acre be used for seedings of 456 lettuce made during May on muck soils in New York. Adequate nitrogen is especially important for early plantings but is also suggested for all spring seedings because it may hasten maturity of the lettuce and thus may possibly reduce losses from aster yellows. The strain is not recommended for plantings to be cut in the fall when tipburn and bolting are usually not serious problems.

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Yields of Cantaloupes as Affected by Time of Placement of Manures in Furrows[1]

By E. M. Rahn, *University of Delaware, Newark, Del.*

The placement of animal manures, especially horse and cow manures, in furrows or hills 4 to 8 inches below the seed for growing cantaloupes as well as other cucurbits in an ancient practice. This is still recommended in order to obtain high yields but it is being discontinued by many growers in Delaware and other cantaloupe growing sections due to lack of sufficient manures. Poultry manure, however, in Delaware is abundant but its use in furrows in a year of subnormal rainfall may cause injury to seedlings as reported by Rahn and Phillips (1). They report that in a dry year poultry manure was most effective when broadcast. The question of how long animal manures should be in the furrow or hill and covered with soil previous to seeding has never been reported in the literature as far as the writer knows. Most growers in Delaware place manures in furrows or hills 1 to 5 months previous to seeding. Many claim that it is best for manure to be in the soil for several months so as to further decompose and become incorporated with the soil. It was particularly felt that poultry manure if placed in furrows long before seeding would be more effective for cantaloupe production and no injury to seedlings would occur. The work reported herein was conducted in 1945 and 1946 to definitely ascertain the relation between cantaloupe yields and the time of placement of horse manure and poultry manure in furrows previous to seeding.

EXPERIMENTAL METHODS

Two kinds of manures were used, partially decomposed horse manure, and broiler manure direct from broiler houses with peanut hull litter. Both manures were applied in furrows 8 inches deep at the same rate, 5 tons per acre, at three different times: (a) approximately 1 week before seeding, (2) approximately 1 month before seeding, and (3) approximately 5 months before seeding. In 1945 seeding occurred on April 27 and manures were applied and covered for this season on April 18 and March 21, 1945, and November 25, 1944. In 1946 seeding occurred on April 23 and manures were applied and covered for this season on April 15 and March 8, 1946, and November 23, 1945. Analyses of the manures used are given in Table I.

TABLE I—ANALYSES OF MANURES USED (PERCENTAGES BASED ON WEIGHT WHEN APPLIED)

Year	Nitrogen (N)		Phosphorus (P_2O_5)		Potash (K_2O)		Moisture	
	Horse	Broiler	Horse	Broiler	Horse	Broiler	Horse	Broiler
1945	1.14	3.14	0.52	1.16	0.81	1.16	46.00	14.96
1946	0.30	0.79	0.14	0.95	0.19	0.67	82.00	56.40

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[1] Published as Miscellaneous Paper No. 25 with the approval of the Director of the Delaware Agricultural Experiment Station, Contribution No. 11 of the Department of Horticulture.

As is customary all manure treatments were supplemented with an application of commercial fertilizer. Commercial fertilizer of a 4–8–12 analysis at the rate of 800 pounds per acre was applied at seeding time in bands 3 inches deep and 6 inches from the row. Seed of the Jumbo Hale's Best variety was planted in rows 6 feet apart. The plants were ultimately thinned to stand 2 feet apart in the row. Each of the six treatments was replicated five times in a randomized block arrangement and each plot consisted of three 50-foot rows. Only the center row was used for taking yield records.

RESULTS AND DISCUSSION

Yield results are presented in Table II. They include marketable melons; early marketable melons, those harvested during the first 10 days of the season; jumbos, marketable melons 5 inches or more in diameter; and average weight of melons in pounds. Average yields given in Table II indicate that it was best to place manures in furrows a month previous to seeding for the highest early and total yields and a week previous to seeding for the highest yield of jumbos. Placement of manures in furrows 5 months previous to seeding resulted in considerably lower yields in most cases, possibly because some of the soluble plant nutrients had been lost during the winter months by leaching. It must be pointed out that these conclusions cannot in all cases be substantiated by yields that were significantly superior on a statistical basis but these yields were actually consistently superior for both years and both manures by relatively high percentages in most cases. The average total yield when horse manure was applied in fur-

TABLE II—YIELDS PER ACRE OBTAINED WHEN FIVE TONS PER ACRE OF HORSE AND BROILER MANURE WERE PLACED IN FURROWS FOR VARYING LENGTHS OF TIME PREVIOUS TO SEEDING IN THE 1945 AND 1946 SEASONS

Treatment—Approximate Time Intervals Between Seeding and Manure Application	Marketable Melons			Early Marketable Melons			Jumbos			Average Weights of Melons (Lbs)		
	1945	1946	Average	1945	1946	Average	1945	1946	Average	1945	1946	Average
Horse manure; 5 months.	7,547	3,949	5,748	4,821	1,771	3,296	5,460	1,684	3,572	3.0	2.6	2.8
Horse manure; 1 month ...	8,737	4,240	6,489	5,256	2,875	4,066	5,779	1,917	3,848	2.8	2.5	2.7
Horse manure; 1 week	8,766	3,601	6,184	5,198	1,539	3,369	6,273	1,684	3,979	2.9	2.6	2.8
Broiler manure, 5 months ..	7,983	3,746	5,865	5,169	1,742	3,456	5,750	1,539	3,645	2.9	2.5	2.7
Broiler manure; 1 month ..	8,070	5,692	6,881	5,256	3,398	4,327	5,808	2,526	4,167	2.9	2.6	2.8
Broiler manure, 1 week	7,954	5,343	6,649	4,501	2,701	3,601	5,692	3,136	4,414	3.1	2.8	3.0
Difference required for significance	Insignificant	1,118	—	Insignificant	1,015	—	Insignificant	887	—	—	—	—

rows 1 month previous to seeding was 6,489 melons per acre. This represents 13 and 5 per cent increases in yield, respectively, over the yields obtained when manure was placed in furrows 5 months and 1 week before seeding. Comparable figures for broiler manure were 6,881 melons when applid 1 month previous to seeding, which represents 17 and 3 per cent increases in yield, respectively, over the yields obtained when manure was placed in furrows 5 months and 1 week before seeding. These percentages show that these manures were most effective when placed in furrows a month before seeding although the total yields were not appreciably depressed if this time interval was shortened to a week.

The early yields, however, were depressed by a time interval as short as a week between placement of manure in furrows and seeding as shown by early yields recorded in Table II. The average early yield when horse manure was applied in furrows 1 month previous to seeding was 4,066 melons per acre, which is 23 and 21 per cent greater, respectively, than yields obtained when manure lay covered up in the furrow for 5 months and 1 week. Similarly, broiler manure effected an average early yield of 4,327 melons per acre when placed in furrows 1 month previous to seeding. This yield represents 25 and 20 per cent increase in yield, respectively, over the yields obtained when manure was placed in furrows 5 months and 1 week before seeding.

As for yield of the large jumbo melons, there were indications that a time interval of 1 week between manure placement and seeding was at least as good or better than a time interval of a month. When horse manure was placed in furrows 1 week before seeding, the average yield of jumbos was 3,979 per acre. This yield was slightly better, 3 per cent, than the yield obtained when the time interval between manure placement and seeding was 1 month. It was 10 per cent better than when the time interval was 5 months. Similarly, when broiler manure was placed in furrows 1 week before seeding the average yield of jumbos was 4,414 per acre, 6 and 17 per cent better, respectively, than when the manure was placed in furrows 1 and 5 months before seeding. Further indication that the largest melons were produced when manure was placed in the furrow only a week before seeding was the fact that the average weight of marketable melons was 3.0, 2.8, and 2.7 pounds, respectively, when broiler manure was placed in the furrow 1 week, 1 month, and 5 months previous to seeding. Apparently fewer but larger fruits resulted when manure was placed in the furrow only a week previous to seeding with an accompanying delay in maturity.

SUMMARY

When horse manure and broiler manure were placed in furrows for cantaloupe production 1 week, 1 month, and 5 months before seeding, the greatest total and early marketable yields resulted when this time interval was 1 month, while the greatest jumbo yields resulted when this time interval was 1 week. The month-interval treatment was particularly superior to the other two treatments in early marketable yields and to the 5 month-interval treatment in total marketable yields.

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1. RAHN, E. M., and PHILLIPS, W. H. The effect of various fertilizer and manure treatments on the yield, size, stand, and disease resistance of cantaloupes. *Del. Agr. Exp. Sta. Bul.* 256. 1945.

A New Transplanter for Sweetpotatoes and Other Vegetables[1]

By JOHN A. CAMPBELL, *Truck Crops Branch Experiment Station, Crystal Springs, Miss.*, and O. A. BROWN, *Bureau of Plant Industry Station, Beltsville, Md.*

TRANSPLANTERS have been standard equipment of vegetable growers in the Middle West, certain sections of the East, Florida, and the Rio Grande Valley section of Texas for some time.

Most transplanters have been designed to be used under the cultural methods adapted to those particular sections, where the fields are usually large with long straight rows. Because of the differences in sizes of the fields, topography of the land, and height of ridges or beds used, which exist between the areas just named and the Copiah vegetable growing area, most commercial transplanters are not adapted to the Mississippi growers' needs. They are usually, if not always, built as a sulky unit, and are either horse- or tractor-drawn. When tractor-drawn, these types are unwieldy in small or terraced fields, since a large space is required in which to turn and it is difficult to follow crooked rows. Therefore, they are not used to any great extent in the sweetpotato, commercial cabbage, and tomato producing areas of Mississippi where the large majority of fields are relatively small. It was for these reasons that the tractor transplanter attachment shown in Fig. 1 was designed and its performance studied at the Truck Crops Branch Experiment Station at Crystal Springs.

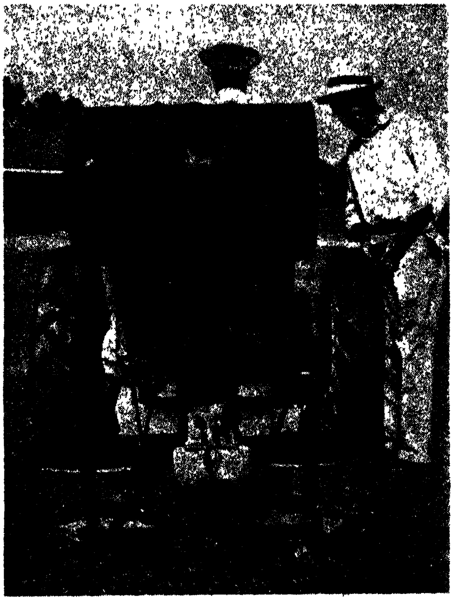

FIG. 1. Transplanter mounted on Farmall Model A tractor, complete with watering attachment.

Mechanical transplanters suitable for conditions in small fields have been developed and used profitably for the setting of sweetpotatoes in the Laurel, Mississippi area, as was reported in Mississippi Experiment Station Bulletin No. 392 by John W. Randolph and W. S. Anderson. Experimental work has shown that suitable transplanters can be used to a great advantage in the Copiah truck growing area for setting cabbage, tomato, and pepper plants. This is especially true for the growers who use tractors in their farm operations, as so many are now doing.

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[1] Contribution from the Truck Crops Branch Experiment Station, Crystal Springs, Mississippi. Published with the approval of the Director, Mississippi Agricultural Experiment Station, State College, Mississippi; Paper No. 131, New Series.

The transplanter shown in Fig. 1 is mounted in the rear of a tractor. It rides principally on the drawbar and is pulled in somewhat the same manner as certain plow attachments, such as the middlebuster. It is of simple design and is easily assembled. Certain parts[2] of a standard transplanter which were used are listed below and shown in Figs. 2 and 3:

1. One seat bar assembly.
2. One shoe assembly with 4-inch runner and pressure plates.
3. Two droppers seats.
4. Two foot rests and leg shields.

Fig. 2 shows the parts that were shop made and which are necessary to complete the attachment. The front cross bar is attached to the front bolts of the rear axle housing of the tractor.

The frame of the shoe assembly is attached to the front cross bar,

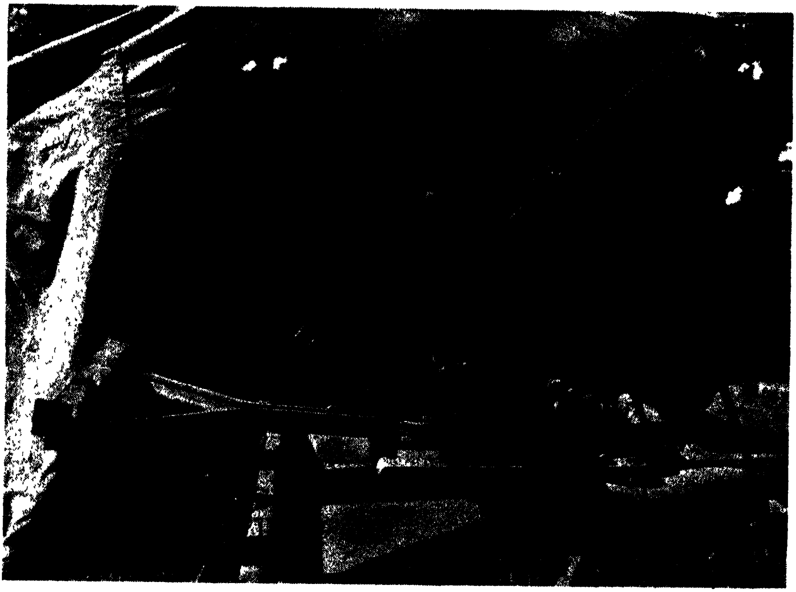

FIG. 2. Parts of standard transplanter: A, seat bar assembly; B, shoe assembly with runner and pressure plates; C, foot rests. Shop made parts: D, front cross bar and support arms; E, adjustable lever; F, rear cross bar and support arms.

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[2] A list of transplanter parts may be obtained by writing to The Mississippi Agricultural Experiment Station.

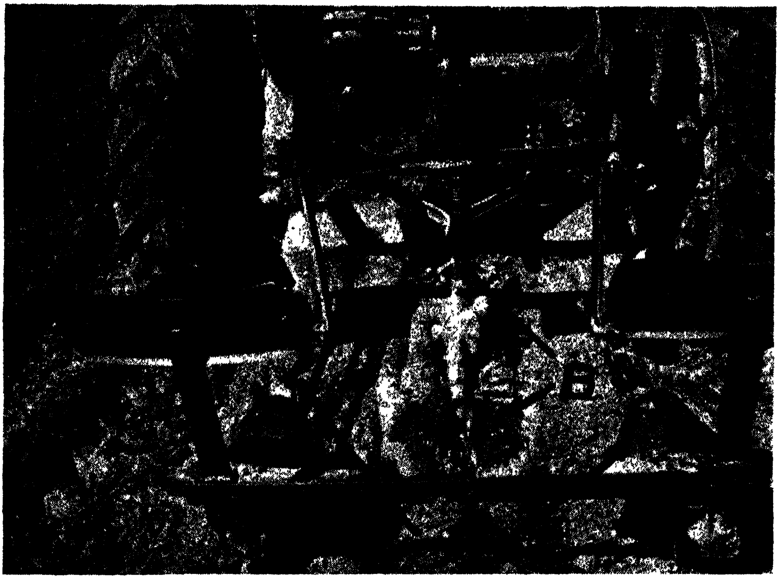

FIG. 3. Transplanter mounted on tractor showing parts: A, seats and seat bar assembly; B, shoe assembly; C, foot rests and leg shields; F, rear cross bar and support arms.

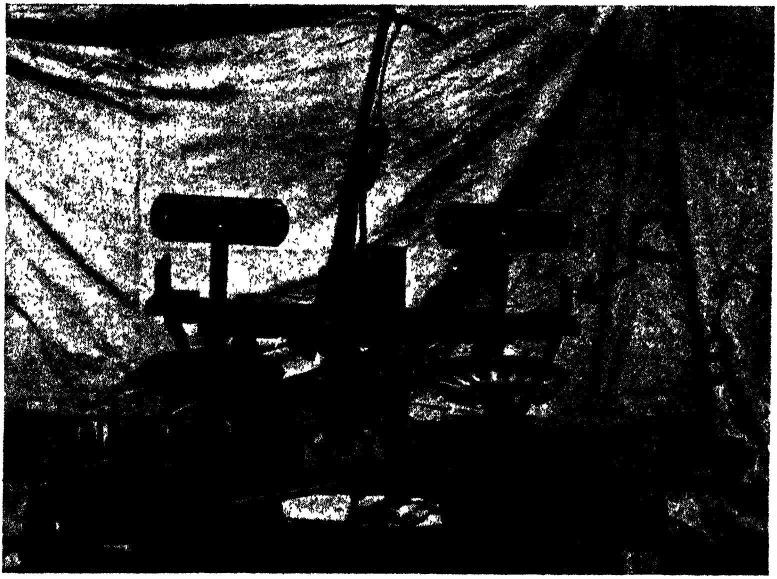

FIG. 4. Front view of transplanter: A, brackets welded to front cross bar for stationing front support arms and Y frame of shoe assembly; B, bracket for bolting the front cross bar to the front holes of the rear axle housing; C, brackets to support V frame which carries water barrel.

and the support arms fastened to the front ends of the seat bars. The rear cross bar, to which the adjustable lever is welded, fastens on top of the tractor drawbar (see Fig. 3), and the support arms are attached to the seat bars. Thus, the seat bar assembly and seats are made stationary to the tractor and can be adjusted for height by raising or lowering the drawbar to obtain the correct position for the operator.

The shoe assembly (runner and pressure plates), which is attached to the front cross bar through the Y frame, is free to pivot and is adjusted for depth by the adjusting lever. Constant pressure is maintained on the runner and pressure plates through the coil spring which connects the lever to the shoe assembly. The pressure plates are interchangeable with pressure rollers. The adjustable water valve assembly which feeds the water into the furrow made by the runner is shown in Fig. 5.

The attachment of the frame, for the water barrel, to the brackets of the rear cross bar and fender is also shown in Fig. 5. Both the front and rear cross bars are made from ½-inch by 2-inch strap iron. The arm supports and brackets are made from $^5/_{16}$ inch by 1½ inch strap iron. The V frame for the water barrel is made from light angle iron. Four machine bolts are required to attach the transplanter to the tractor.

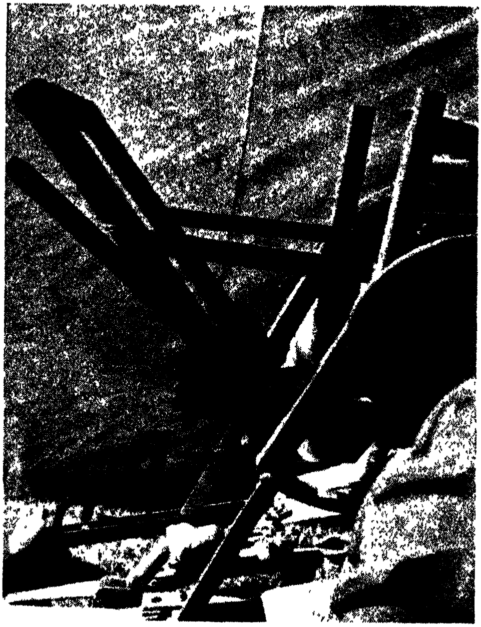

FIG. 5. V-Frame attachment for water barrel: A, frame fastened to brackets on rear cross bar; B, frame bolted to fender of tractor; C, water valve assembly.

Trial runs were made to compare the man-hours required to set tomatoes by the hand trowel method, which is most commonly used in the Copiah area, and the mechanical transplanter shown in Fig. 1. Table I shows the number of man-hours required with each method.

The speed in setting plants by any method will vary with the crop and the spacing used for the plants. A study of the recovery of both cabbage and tomato plants set by the two methods, shown in Table I, indicated that there was no appreciable difference in the recovery of the plants. Almost 100 per cent recovery was obtained with cabbage and tomatoes without the use of the watering attachment when there was an ample supply of moisture in the soil. However, under drier

TABLE I—COMPARISON OF MECHANICAL TRANSPLANTER WITH HAND TROWEL METHOD OF SETTING TOMATO PLANTS

Method Used	Man-Hours Required to Set an Acre of Tomatoes Spaced 2 Feet Apart on 4 Foot Rows
Hand trowel	15.0
Tractor transplanter attachment (Fig. 1)	4.5

conditions the watering attachment had to be used in order to maintain satisfactory recovery of plants. In certain soil types the pressure rollers may prove more satisfactory than the pressure plates on the transplanter.

Because of its adaptability to local cultural methods and small fields the transplanter attachment is being used to replace the hand trowel method at the Truck Crops Branch Experiment Station. Several growers in the Crystal Springs area are now using this design exclusively for transplanting cabbage, tomatoes, and pepper plants.

FIG. 6. Setters transplanting tomatoes with tractor attachment.

The advantages of the tractor attachment, shown in Fig. 1, when compared with the standard type which is mounted on two wheels, are listed as follows:

1. It is of simple design and construction.
2. It is inexpensive and easy to make.
3. It utilizes the support and mobility of the tractor.
4. It can be used in any small field where a one-row tractor is used.

It will follow any row made or prepared by the same tractor. Short turns can be made and it can be easily backed when necessary.

5. Water and fertilizer can be applied at the same time by using the regular fertilizer attachment for the one-row tractor.

6. It can be attached or removed quickly, only four bolts being required for attaching transplanter to the tractor.

A Successful Method of Utilizing Glass Plant Protectors[1]

By E. P. BRASHER, *Delaware Agricultural Experiment Station, Newark, Del.*

IN THE past twenty-five years, many different types of plant protectors have been used by commercial vegetable growers in an attempt to increase the earliness and profits of certain vegetable crops. Practically all of these protectors have been discarded because of expense, undesirable results, or the amount of labor involved in their use. In Michigan, Hibbard (3) reported that plant protectors were of undoubted value in one year out of six; of doubtful value in two; and of no value in three. In Arkansas, Ware (4) gave a more favorable report on the use of protectors after four years of experimenting with many different types. Hepler (2) regarded glass casseroles of no value in New Hampshire because they produced excessive temperatures during sunny days even when the outside temperature was only 65 degrees F and because the night temperatures under them did not vary much from the outside temperature. Brasher (1), however, in 1945 conducted studies with glass plant protectors which showed potential possibilities for commercial use with certain vegetable crops. Although he was able to significantly increase the early yield of tomatoes, pole lima beans, sweet corn, and cantaloupes, a great deal of labor was involved in frequent adjustment and sometimes removal of protectors to avoid excessive temperatures and humidity as well as to prevent damping-off.

From these studies it was obvious that a commercially successful plant protector must increase early yields and must not require daily attention. Since glass protectors definitely met the former requirement, the motive of this investigation was to find a successful method to eliminate the labor of daily attention and at the same time to maintain a high level of productivity in early yields.

MATERIALS AND PROCEDURE

Two crops, cantaloupes and watermelons, were planted using the Jumbo Hale's Best and the Coker varieties, respectively. Sixteen treatments were used with cantaloupes and 11 with watermelons. These treatments involved the use of mixing bowls and casseroles of various sizes with and without holes for ventilation; mixing bowls with lower emissivity coefficients than ordinary glass; paper caps; casseroles removed at three intervals after seedling emergence; and two open-culture treatments planted on different dates. All of these protectors were handled only twice, once to place them over the hill and once to remove them. This study was conducted on a Sassafras loamy sand at the Substation, near Georgetown, Delaware. The treatments were replicated four times in a randomized block arrangement. Each repli-

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[1] Published as Misc. Paper No. 21 with the approval of the Director of the Agricultural Experiment Station. Contribution No. 6 of the Department of Horticulture, November, 1946.

This study was made possible by a grant from the Corning Glass Works, Corning, New York.

cation consisted of a row 50 feet long. The cantaloupe hills were spaced 4 by 6 feet and the watermelons 4 by 12 feet. The cantaloupe hills were finally thinned to two plants per hill and the watermelon hills to one plant. All cultural treatments within each experiment were uniform.

RESULTS

Temperatures:—Since seedling emergence is influenced greatly by temperatures, it is necessary for a plant protector to provide a warmer seed bed and a warmer air temperature for early plant growth if early yields are to be substantially increased. Temperature readings were, therefore, recorded at various times to determine the difference between soil temperatures under the protectors and that in the open. Wide difference in soil temperature existed between the open soil and that covered with glass protectors during a period when the sun was bright as shown in Table I. At the 1-inch depth, where the cantaloupe and watermelon seeds were planted, the soil was 8 to 15 degrees F warmer. Even at a 4-inch depth, the soil under the glass protectors was warmer than that in the open. Under the Hotkaps, however, the soil at all depths up to 4 inches was cooler than that in the open.

TABLE I—SOIL AND ATMOSPHERIC TEMPERATURES IN OPEN AND UNDER PROTECTORS (CANTALOUPE AND WATERMELON PLANT PROTECTOR STUDY, GEORGETOWN, DELAWARE, 1946)

Treatment	Temperature (Degrees F) at 2·00 P M, May 6—Bright Sun				
	½ Inch Above Soil Surface	1 Inch Under Soil Surface	2 Inch Under Soil Surface	3 Inch Under Soil Surface	4 Inch Under Soil Surface
Open culture	88	82	79	75	72
Hotkaps	91	79	75	73	70
2-quart casserole without ventilation	108	95	88	81	75
2½-quart mixing bowl with ⅛-inch hole	106	90	88	81	75
2½-quart mixing bowl with ¼-inch hole	104	95	90	84	79
2½-quart mixing bowl with ½-inch hole	102	90	84	79	75
2½-quart mixing bowl with 1-inch hole	102	91	86	81	75
1½-quart mixing bowl with ¼-inch hole	102	91	82	77	73
1-quart mixing bowl with ¼-inch hole	99	93	86	77	75
3-quart casserole with ½-inch hole	102	97	90	84	79
7-inch sealed beam reflector with three, ⅛-inch holes	104	95	88	81	75
2½-quart mixing bowl with ¼-inch hole and coated with S8* coating on outside surface	99	90	84	79	73
2½-quart mixing bowl with ¼-inch hole and coated with S16* coating on inside and outside surface	97	95	88	77	75

*Special coatings to provide lower emissivity coefficients than ordinary glass.

The soil temperatures at the 1-inch depth fell rapidly in the evening and by early morning the soil under the glass protectors and that in the open was nearly equal.

The difference in atmospheric temperature under the glass protectors and that in the open was much greater than the difference that occurred in the soil. On bright days there was sometimes a 27 degree F difference. On cloudy days the difference was not so great but still it was usually 4 or 5 degrees warmer under the glass protectors. In the early morning before sunrise, the atmospheric temperature was usually about one degree warmer under the protectors. Although there was a tendency for the ventilated glass protectors to be slightly cooler than unventilated protectors during the periods of bright sunshine no relationship could be found between hole size and air temperature.

Thermographic temperature records were taken during the period that the protectors remained over the seeds and young plants. During this period (April 15 to May 20), the outside temperature ranged between 20 degrees F and 85 degrees F. The lowest temperature occurred before the seedlings emerged but on two occasions after emergence, freezing temperatures (28 and 29 degrees F) occurred without damaging any of the plants under the protectors.

Seedling Emergence:—The cantaloupe and watermelon seeds were planted on April 15, a date fully 10 days in advance of the earliest commercial planting. On April 22, many of the seeds which were planted under the glass protectors had produced young seedlings in spite of the fact that on five of the seven nights the temperature fell below 32 degrees F. On April 24 counts were made of the number of seedlings appearing above ground. These records appear in Table II and show that a large percentage of the seeds under the glass protectors had produced seedlings while none had appeared above ground in the open and only a few under the paper Hotkaps.

TABLE II—EMERGENCE RECORD OF CANTALOUPE AND WATERMELON SEEDLINGS 9 DAYS AFTER SEEDING

Treatment	Percentage of Hills Containing Two or More Plants Above Ground (Average of Four Replications)	
	Cantaloupe	Watermelon
1. Open culture	0	0
3. Hotkaps	15	0
4. 2-quart casserole without ventilation*	85	—
5. 2-quart casserole without ventilation*	73	—
6. 2-quart casserole without ventilation	65	79
7. 2½-quart mixing bowl with ⅛-inch hole	81	83
8. 2½-quart mixing bowl with ¼-inch hole	88	83
9. 2½-quart mixing bowl with ½-inch hole	77	85
10. 2½-quart mixing bowl with 1-inch hole	73	77
11. 1½-quart mixing bowl with ¼-inch hole	60	81
12. 1-quart mixing bowl with ¼-inch hole	58	65
13. 3-quart casserole with ½-inch hole	73	92
14. 7-inch sealed beam reflector with three, ⅛-inch holes	50	63
15. 2½-quart mixing bowl with ¼-inch hole and coated with S8 coating on outside surface*	46**	—
16. 2½-quart mixing bowl with ¼-inch hole and coated with S16 coating on inside and outside surface*	54**	—

*These treatments were not included in the watermelon study.
**Average for two replications.

It was evident by May 5 that the seeds planted on April 15 in the open soil were not going to germinate, so more seeds were planted. Although practically a perfect stand was obtained under the protectors a number of plants died because of damping-off and extreme heat during bright sunny days. New plantings were made if the cantaloupe and watermelon hills did not contain two healthy plants and one healthy plant respectively. The percentage of replanted hills in all treatments appear in Table III.

TABLE III—PERCENTAGE OF HILLS COMPLETELY OR PARTLY REPLANTED IN CANTALOUPE AND WATERMELON PLANT PROTECTOR STUDY

Treatment	Average of Four Replications	
	Cantaloupe	Watermelon
1. Open culture—planted April 15	98	98
2. Open culture—planted April 25	—	—
3. Hotkaps	42	40
4. 2-quart casserole without hole—removed when germination was complete*	65	—
5. 2-quart casserole without hole—removed one week after germination*	15	—
6. 2-quart casserole without hole—removed two weeks after germination was complete	21	42
7. 2½-quart mixing bowl with ⅛-inch hole	17	46
8. 2½-quart mixing bowl with ¼-inch hole	21	42
9. 2½-quart mixing bowl with ½-inch hole	6	58
10. 2½-quart mixing bowl with 1-inch hole	8	42
11. 1½-quart mixing bowl with ¼-inch hole	15	65
12. 1-quart mixing bowl with ¼-inch hole	23	63
13. 3-quart casserole with ½-inch hole	17	58
14. 7-inch sealed beam reflector with three, ⅛-inch holes	25	65
15. 2½-quart mixing bowl with ¼-inch hole and coated with S8 coating on outside surface*	20**	—
16. 2½-quart mixing bowl with ¼-inch hole and coated with S16 coating on inside and outside surface*	16**	—

*These treatments were not included in the watermelon study.
**Average for two replications.

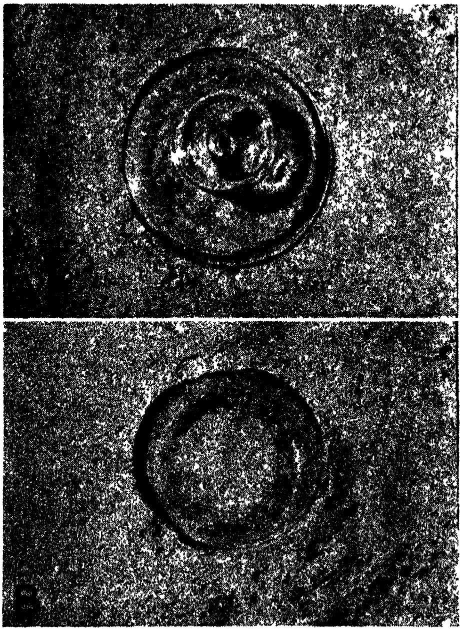

FIG. 1. Showing ventilated (A) and non-ventilated (B) glass plant protectors. Note the collection of moisture under the non-ventilated type.

Early Plant Growth:—The cantaloupe and watermelon plants under the protectors had made excellent growth by May 10 and true leaves were showing on practically all plants. In the open-culture treatments, only a few of the plants had appeared above ground. From May 10 until the protectors were removed (May 20), the growth was neither as rapid nor as luxuriant as it had been previously. A check of the thermographic records revealed the reason. Prior to May 10 the outside temperature reached 70 degrees F. only on a few occasions, but after that date it was common for the temperature to rise to 80 degrees or more. These temperatures were too high for successful plant growth. An outside temperature of 80 degrees F usually meant that the temperature under the glass protectors was considerably over 100 degrees. High humidity accompanied high temperature. This created an excellent condition for damping-off, a disease which together with high temperatures killed numerous plants. When the protectors were ventilated with ½-inch and 1-inch holes, the severity of damping-off as shown in Table III by the number of hills of cantaloupes replanted, was lessened but the plants were stunted by the extreme heat.

The cantaloupe plants in treatment No. 5 (protectors removed 1 week after germination) and the watermelon plants in treatment No. 6 (protectors removed 2 weeks after germination) appeared to be in a more vigorous condition by June 15 than the plants in any other treatment. However, the plants in all treatments definitely improved rapidly after the protectors were removed and very little difference could be observed between any of the plants in the glass protector treatments by July 1. Although many plants were damaged by damping-off and extreme heat before the protectors were finally removed, the plants which survived were much further advanced than the open-culture plants. In Fig. 2, a comparison of a typical cantaloupe plant produced under a glass protector and one produced in the open is made. A similar difference existed in the watermelon plants. The cantaloupe plants were more resistant to damping-off and heat than the watermelon plants. This is shown in Table II by the larger number of watermelon hills that were reseeded.

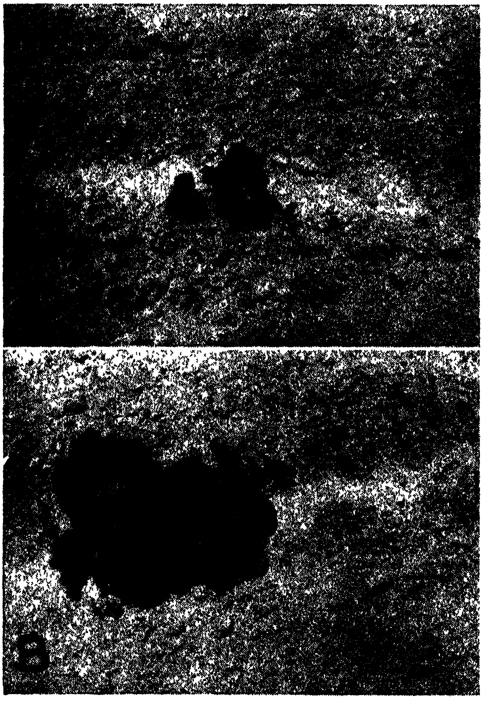

FIG. 2. A comparison of a typical cantaloupe plant started in the open (A) and one under a glass protector (B). The seed for both plants were planted at the same time.

Cantaloupe Yields:—Early yield (July 31 to August 10 inclusive) and total yield of number and weight of marketable melons were recorded. During the early part of the season, the melons were harvested every other day, but as the season advanced they were harvested every day. Only melons in the full slip stage were picked. These records, presented

TABLE IV—Yield Records from Cantaloupe Plant Protector Study

Treatment	Early Yield (July 31 to August 10 Inclusive) per Acre of Marketable Melons		Total Yield Per Acre of Marketable Melons	
	Number	Weight (Lbs)	Number	Weight (Lbs)
1. Open culture; planted April 15	334	698	2,151	6,788
2. Open culture; planted April 25	945	2,674	3,387	10,436
3. Hotkaps	1,206	2,776	3,779	10,494
4. 2-quart casserole without hole; removed when germination was complete	1,352	3,270	3,343	8,750
5. 2-quart casserole without hole; removed one week after germination	2,733	6,163	3,895	10,247
6. 2-quart casserole without hole; removed two weeks after germination was complete	2,471	5,698	3,852	10,959
7. 2½-quart mixing bowl with ⅛-inch hole	2,805	6,657	4,142	10,858
8. 2½-quart mixing bowl with ¼-inch hole	2,878	6,555	3,779	9,433
9. 2½-quart mixing bowl with ½-inch hole	2,878	6,831	3,561	9,608
10. 2½-quart mixing bowl with 1-inch hole	2,660	5,930	3,852	10,014
11. 1½-quart mixing bowl with ¼-inch hole	2,224	5,625	3,241	9,797
12. 1-quart mixing bowl with ¼-inch hole	1,206	2,921	3,169	8,866
13. 3-quart casserole with ½-inch hole	2,762	6,512	3,415	9,244
14. 7-inch sealed beam reflector with three, ⅛-inch holes	1,526	3,634	3,314	9,419
15. 2½-quart mixing bowl with ¼-inch hole and coated with S8 coating on outside surface	2,180*	6,133*	3,343*	9,549*
16. 2½-quart mixing bowl with ¼-inch hole and coated with S16 coating on inside and outside surface	2,471*	5,203*	3,779*	9,318*
Difference necessary for significance	1,030	2,788	1,230	3,180

*Average for two replications.

in Table IV, show that practically all of the plants started under glass protectors produce significantly greater early yields than the plants started in the open and under the paper Hotkaps. The largest early yields occurred in those treatments which had a ¼- or a ½-inch hole in the protectors for ventilation and in the treatment where the protectors were removed 1 week after germination. In some cases, the difference in early yield between the open-culture and glass-protector treatments amounted to as much as 2,544 melons per acre. When comparing the paper Hotkaps with the best glass protectors, the difference in early number of melons amounted to 1,672 in favor of the glass protector. In total yields, many of the glass protector treatments produced significantly more melons than the open-culture treatment all of which were seeded on April 15. This was not true, however, with the open-culture treatment which was seeded on April 25.

Watermelon Yields:—The early (August 7 to 16 inclusive) and total yields of number and weight of watermelons are presented in Table V. These records show that no melons were harvested from the open-culture treatment during the first 10 days of the harvest season, while all the other treatments yielded melons ranging from 18 to 91 per acre. In total yield, the difference between unprotected and protected plants was not great and in some cases the unprotected plants produced a larger yield than did the protected plants. However, in treatment 6 (protectors removed 2 weeks after germination), the weight of melons was significantly greater than any other treatment except the paper Hotkaps.

TABLE V—Yield Records from Watermelon Plant Protector Study

Treatment	Early Yield (Aug 7 to 16 Inclusive) Per Acre		Total Yield Per Acre	
	Number	Weight (Lbs)	Number	Weight (Lbs)
1. Open culture; planted April 15	0	0	473	7,658
3. Hotkaps	18	455	582	10,013
6. 2-quart casserole without hole; removed two weeks after germination was complete	73	1,372	582	10,498
7. 2½-quart mixing bowl with ⅛-inch hole	55	979	509	7,809
8. 2½-quart mixing bowl with ¼-inch hole	73	1,475	382	5,955
9. 2½-quart mixing bowl with ½-inch hole	91	2,011	400	6,527
10. 2½-quart mixing bowl with 1-inch hole	55	1,452	436	6,825
11. 1½-quart mixing bowl with ¼-inch hole	18	400	418	6,613
12. 1-quart mixing bowl with ¼-inch hole	18	385	527	7,616
13. 2½-quart casserole with ½-inch hole	36	576	455	6,800
14. 7-inch sealed beam reflector with three, ⅛-inch holes	18	286	346	5,685
Difference necessary for significance	—	—	220	1,228

Discussion

Heavy glass plant protectors such as used in this study have obvious advantages over many of the paper protectors. They can be dropped into place from a standing position, wind of even gale velocity will not shift them, they increase the mean soil temperature, they admit sufficient light for good plant growth, and they will last indefinitely if handled carefully. They do, however, have some faults. Due to their weight, they fit closely to the ground preventing adequate ventilation. On bright days, even though the outside temperature is not more than 70 degrees F the temperature under the protectors may exceed 100 degrees F and the relative humidity may approach 100 per cent. This creates an excellent condition for damping-off. Other faults of minor importance include bulkiness and expense.

The most serious faults, those of damping-off and producing excessive temperature, can be prevented to a great extent by good management practices. The seed should be treated with a recommended fungicide, which is a good practice even though plant protectors are not used. The planting date should occur at a time which is about 10 days in advance of the regular planting season. After germination the protector should be removed as soon as weather conditions permit. If cool temperatures (below 70 degrees F) persist, it is advantageous to leave the protectors over the young seedlings. However, if warm temperatures occur, the protectors should be removed. At this season of the year, no more frosts are likely to occur, thus the work of adjusting or removing protectors can be eliminated. Therefore, the placement and removal of the protectors would be the only labor expense involved in their use. The monetary value of these operations is estimated to be ten dollars per acre for cantaloupe and five dollars for watermelon. By following this practice, the early yield of cantaloupes from the best plant protector treatment was increased by 1788 melons per acre over the best open-culture treatment; with watermelons the increase was 73 per acre. From these increases, it appears that it would be economically sound to start watermelon and cantaloupe plants under glass plant protectors if a premium on early yields could be secured.

Under the experimental conditions existing in 1946, it appeared that the greatest benefit derived from the use of the protectors was in accelerating germination and protecting the plants from cold injury for 1 week after germination. This is conclusively shown by the cantaloupe germination record in Table II and yield record in Table IV. Cantaloupe seed planted in the open on April 15 failed to germinate while the seed planted under the glass protectors germinated almost perfectly. A comparison of the early number of melons in treatments 4, 5, and 6 (protectors removed when germination was complete, protectors removed 1 week after germination, and protectors removed 2 weeks after germination respectively) actually shows a huge benefit in favor of leaving the protectors in place for only one week after germination. The yields for treatments 4, 5, and 6 which were 1352, 2733, and 2471 melons respectively would so indicate.

When the protectors were allowed to remain in place for 2 weeks after seedling emergence, it was advantageous for the protectors to possess holes for ventilation. It appeared that a ½ inch hole in a 2- to 2½-quart mixing bowl or casserole was the most desirable. When a 2½-quart mixing bowl was used, it was necessary to replant only 6 per cent of the hills when it contained a ½-inch hole. When this same mixing bowl contained a ¼-inch hole, it was necessary to replant 21 per cent of the hills. Practically all of the replanting was performed because of heat injury or damping-off. The plants started under mixing bowls with lower emissivity coefficients definitely produced inferior yields to those not so treated. The coated surfaces in these mixing bowls were treated so as to reflect the long wave-length radiation from the heated soil under the bowls but to transmit a large percentage of the sunlight energy. Apparently, there was sufficient loss of sunlight energy due to absorption and reflection to reduce the effectiveness of the coated bowls below that of the regular glass bowls with no surface treatments. Also, the small 7-inch sealed beam reflector failed to produce yields comparable to those of larger glass protectors.

From temperature readings and the speed of seedling emergence, it is evident that glass protectors definitely increase soil temperatures. This is true whether the soil is light or heavy. The light soil, of course, warms up more quickly but by the same token a heavier soil, once it has become warm, retains the heat for a longer period. This is substantiated by the temperature readings taken in 1945 on a Sassafras clay loam and in 1946 on a Sassafras loamy sand. In the clay soil, at a depth of 2 inches on a sunny afternoon, the difference in temperature between the open soil and that covered with a glass plant protector was found to be 9 degrees F. By 6:30 o'clock the following morning the soil at a 2-inch depth under the protector was still 5 degrees F warmer than the open soil. In the sandy soil, large differences in soil temperatures existed after a few hours of sunshine, but always on the following morning the soil temperature in the open and that under the protectors were nearly equal. With either soil, however, the mean temperature had been increased sufficiently, by the use of the glass protectors, to speed up the rate of germination by 10 or more days.

From the results of this study, it seems highly probable that glass plant protectors could be used to extend the latitude in which such crops as melons could be grown. They would have the effect of appreciably lengthening the growing season and thus permit planting of crops in areas where the short season between frosts now prevents satisfactory maturing.

SUMMARY

Various types of glass plant protectors were used to cover hills where cantaloupe and watermelon seed had been planted in an attempt to find a method of utilizing glass plant protectors which would increase early yields and not require attention from the time they were placed in the field and the time they were removed.

Soil and atmospheric temperatures were increased under the protectors. At a depth of 1 inch, where the cantaloupe and watermelon seeds were planted, a difference of 15 degrees F sometimes existed between the open soil and that covered with a glass protector.

With both crops tested the plant protectors accelerated seedling emergence by more than 10 days, and protected the young seedlings from freezing when the outside temperature fell to 28 degrees F.

Early yields of both cantaloupes and watermelons were greatly increased by practically all of the glass protectors. During the first 10 days of the harvest season, the best plant protector treatment yielded 2,878 cantaloupes per acre in contrast to 945 cantaloupes for the best open-culture treatment. With watermelons, the contrasting yields were 91 melons per acre for the best protector and none for the open-culture treatment. In total yields, the differences were not great.

The most feasible way of utilizing the glass plant protectors to prevent damping-off and the killing of young seedlings by excessive temperature appears to be as follows: Plant treated seed about 10 days in advance of the regular commercial planting season. After seedling emergence, the protectors are removed as soon as weather conditions will permit. If cool temperatures (below 70 degrees F) persist, it is an advantage to leave the protectors over the plants. However, if warm temperatures occur, the protectors should be removed.

Glass plant protectors containing ½ inch holes had some merits but they failed to significantly increase the early production of cantaloupes over the containers which had no holes and which were removed from the plants 1 week after seedling emergence.

Small 7-inch sealed beam reflectors and glass protectors with lower emissivity coefficients and higher reflectivity and absorption than ordinary glass were not as effective in increasing early yields as other types of glass protectors.

Under the experimental conditions existing in 1946, it would have been economically sound to start watermelon and cantaloupe plants under glass plant protectors if the melons had been sold on a retail market.

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Further Results of Asparagus Fertilizer Studies in Irrigated Central Washington[1]

By W. J. Clore and C. O. Stanberry, *Irrigation Branch Experiment Station, Prosser, Wash.*

THESE studies were conducted as a supplement to an asparagus fertilizer experiment initiated in 1939 at the Irrigation Branch Experiment Station, Prosser, Washington. A description of the plot arrangement, fertilizer treatments, and results from 1939 through 1943 was reported in an earlier publication (1).

In 1944, after five cutting years, it appeared that additional valuable information could be obtained by altering parts of the original experimental design. Six of the 11 untreated plots were selected at random for fertilization. Three of these plots were fertilized with 500 pounds per acre of ammonium sulfate and the remaining three plots received 500 pounds of ammonium sulfate plus 112 pounds of treble superphosphate. The ammonium sulfate was broadcast and the phosphate was placed approximately 4 inches deep and 6 inches to each side of the plot rows. Both applications were made at least a month before the cutting season began.

Results and Discussion

Results of these studies are presented graphically in Fig. 1. The upper part of the figure shows the annual yields of asparagus for two series of plots in tons per acre before and after fertilization and for one series which never received fertilizer. The lower part of Fig. 1 shows the average yields of the fertilizer plots expressed as per cent of the average yield of the unfertilized plots.

Previous to fertilization and until 1945 the N and NP plots generally yielded less than the unfertilized plots. The three plots to be fertilized later with NP gave lower yields than the plots that were to receive N alone. In 1945 and 1946, however, the fertilized plots produced markedly better yields than the continuously unfertilized plots. Average yields from plots receiving nitrogen and phosphorus in combination were greater than those from plots receiving only nitrogen.

Variations in total yields from year to year are not so important as the trends of these yields when the various treatments are compared. Trends in yield response as a result of fertilizers applied can best be studied when unfertilized plot yields are used as a basis. Thus, in the lower part of Fig. 1, the yields from the unfertilized plots are considered as 100 per cent for each of the six years data, and the yields from the N and NP treatments are expressed as per cent of these check yields. Considering that the yields from the N and NP plots averaged lower than check yields before fertilization, the increases in production after fertilization are marked. These data fall just short of significance by an "analysis of variance" due to the variability among

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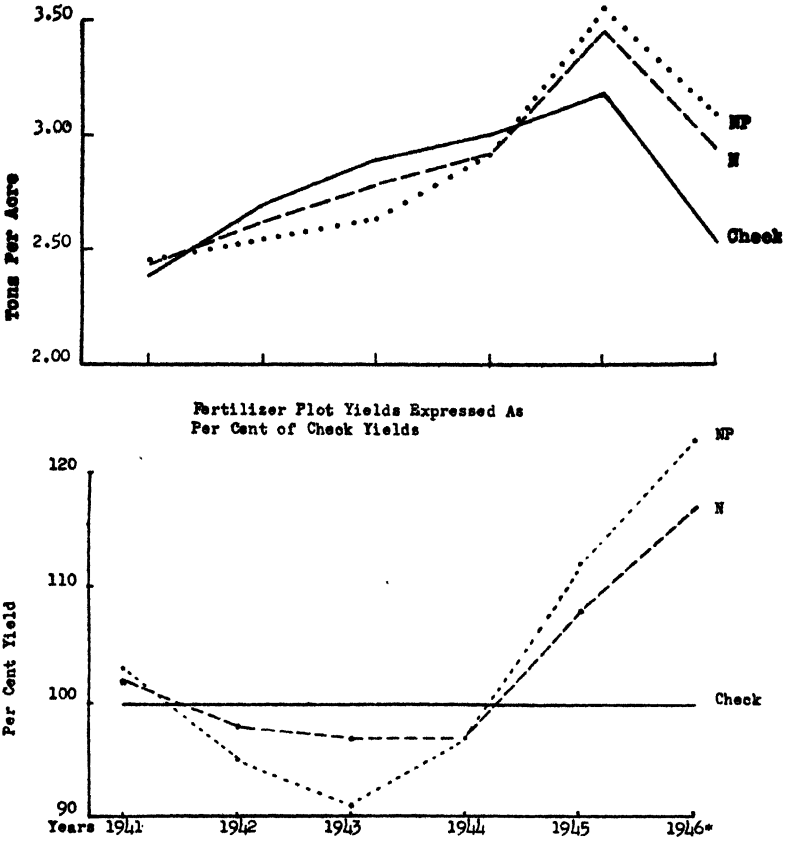
[1] Published as Scientific Paper No. 694 by College of Agriculture, Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman, Washington.



Fertilizer Plot Yields Expressed As Per Cent of Check Yields

FIG. 1. Average annual asparagus yields, (trimmed 8 inches) 1941–1946 from plots before and after fertilizer treatments initiated in 1944.

*Reduction in yield due to short cutting period necessitated by labor shortage.

———— Average of five unfertilized plots.

- - - - - Average of three plots before and after receiving 100 pounds of N per acre annually.

.... Average of three plots before and after receiving 100 pounds of N and 50 pounds of P_2O_5 per acre annually.

individual plots. Although the variability was too great among individual plots to show significance between treatments, all individual fertilizer plots in a given treatment responded similarly and consistently to the fertilizer applied.

These data tend to support the conclusion that substantial increases in asparagus yields cannot be expected the same year the beds are fertilized. On this soil, yield increases can be expected the year after fertilization with nitrogen alone and with nitrogen and phosphorus in combination. In these studies, yield responses in both 1945 and 1946 indicate that the supply of available phosphorus, as well as nitrogen, is limiting asparagus production.

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The Effect of Widely Divergent Dates of Planting on the Heading Behavior of Seven Cabbage Varieties

By J. E. Knott and G. C. Hanna, *University of California, Davis, Calif.*

CABBAGE is produced throughout the year in California. The coastal area is more favorable for market cabbage than is the central valley. Growers in the lower Sacramento Valley can harvest cabbage of good quality normally in fall, winter, and late spring. It is difficult to mature a crop in March and April because plants which should head at that time bolt instead. Late fall and early winter plantings do not reach the heading stage before May. As part of the war emergency program concerning the potentialities and methods of seed production (2, 3) with 12 cabbage varieties, there was an opportunity to note the effect of planting date on head size, production of marketable heads and premature seedstalk development.

METHODS

This report covers only the seven varieties which were included in both the 1943–44 and 1944–45 plantings. The same seed lots were used both years. The plantings were made in a Yolo fine sandy loam. This is a highly productive soil on which crops seldom show a response even to nitrogen; therefore no fertilizer was added. The plants were grown in flats in the open and transplanted to the field when of sufficient size. Plantings of seed were made from July 1 through mid-October at 2-week intervals and at monthly intervals November 1 through February 1.

Twelve varieties were used the first year and seven varieties in the second. In each year there were 14 different dates of planting, although there were only 12 similar dates used in both years. The lack of labor prevented increasing the size of the plantings to include replications.

In 1943–44, 40 or more plants of each variety and date of planting were set out in a single row. Alternate plants had the heads harvested while the others were split when at market maturity to allow the seedstalks to emerge. In 1944–45 adjacent rows of 20 plants each were set out. The heads of one row were harvested while those in the other had the heads split. The diameters of the heads were measured at market maturity whether they were harvested or split.

The first year the rows were singly on beds on 36 inch centers. Copenhagen Market and Jersey Wakefield were spaced 18 inches in the row. The plants of the other varieties were set 24 inches apart. The second year the single rows were on 40 inch beds, and the plants of all varieties spaced 24 inches apart.

The percentages of marketable heads and the diameters of marketable heads are given for the 2 years combined and are based on an average of 82 individuals for each variety for each date of planting for Copenhagen Market and Jersey Wakefield and an average of 69 individuals for the other varieties. The percentage of bolters which is presented for each year separately is based therefore on approximately half as many.

TABLE I—PERCENTAGE OF MARKETABLE HEADS PRODUCED FROM DIFFERENT DATES OF PLANTING (AVERAGE OF 2 YEARS)

Variety	Jul 1 (Per Cent)	Jul 15 (Per Cent)	Aug 1 (Per Cent)	Aug 15 (Per Cent)	Sep 1 (Per Cent)	Sep 15 (Per Cent)	Oct 1 (Per Cent)	Oct 15 (Per Cent)	Nov 1 (Per Cent)	Dec 1 (Per Cent)	Jan 1 (Per Cent)	Feb 1 (Per Cent)
Jersey Wakefield ...	100	100	99	**50.5**	**4**	**45**	97.5	100	98.5	100	100	98.5
Copenhagen Market	98.5	96	96	**47.5**	**0**	**0**	**34**	**47**	**40.5**	75*	97.5	91
Enkhuizen Glory...	99	100	96.5	**32.5**	**2.5**	**24.5**	**51.5**	80	87.5	98.5	95.5	100
Succession..........	100	98.5	93	**28**	**19.5**	62.5	95	96.5	91.5	98.5	90.5	91.5
Slow Bolting Flat Dutch	96.5	86.5	75	**26.5**	**40**	86	97	100	100	98.5	100	98
Penn State Ballhead	97	95	74	**17**	**45**	67.5	92	91.5	95	98	98.5	98.5
Premium Late Flat Dutch...... .	93	97.5	76.5	**4**	**51**	90	86,5	92.5	91	93.5	100	100

*1944–45 only.

RESULTS

Marketable Heads:—The July and February plantings of the quick-growing varieties required about 4 months from seeding to reach mid-harvest of the heads while the October plantings took about 7 months. The intermediate varieties needed 4½ to 5 months and 8 to 8½ months; and the slow growing varieties 5½ to 6 months and about 8½ months to reach mid-harvest from comparable seeding dates. The time from seeding to harvest gradually increased as the date of planting progressed from July to October and decreased as the seeding dates moved from November to February. It took 2 to 3 weeks longer for the heads to reach marketable condition in 1944–45 than it did in 1943–44.

The average percentage of marketable heads for the two years is presented in Table I. When about 50 per cent or less of the plants produced heads the data are in bold face type to emphasize the poor adaptability of quick-growing varieties compared to those of slower growth when plantings are made during the fall months. It will be noted that under the climatic conditions at

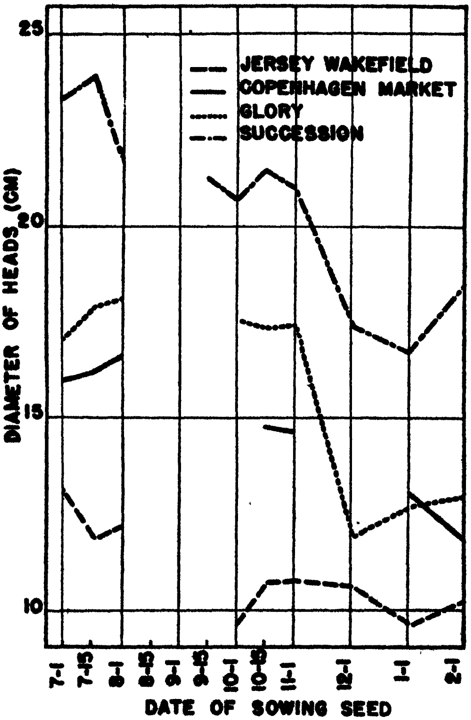

FIG. 1. Effect of date of sowing seed on the diameter of marketable heads of quick-growing varieties.

Davis the quick-growing and intermediate varieties gave few heads from the September plantings. On the other hand the poorest results with the slow-growing varieties were obtained usually from the August 15 plantings. Slow Bolting Flat Dutch headed more satisfactorily and consistently than the other varieties.

Head Diameter:—The average head diameters for the two years are shown in Figs. 1 and 2. When the varieties were planted in July the heads had diameters at market maturity which were about those recognized as characteristic for the variety but the head size changed with planting dates later in the year. The breaks in the graphs occur when the number of bolters in one or both years was so great that the average head diameter of the nonbolters would not have been a reliable figure.

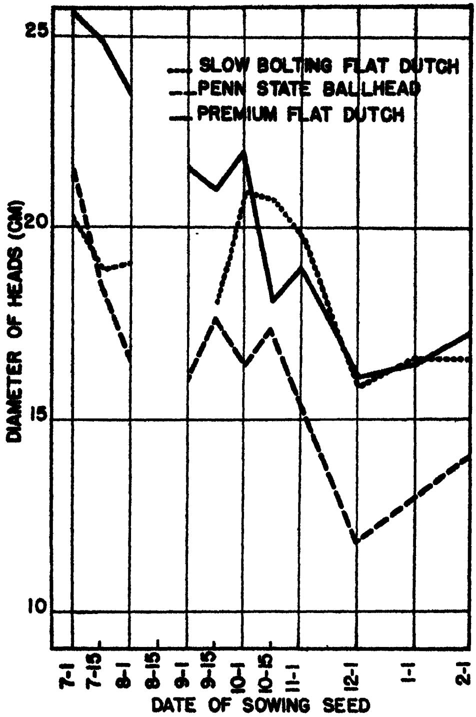

FIG. 2. Effect of date of sowing seed on the diameter of marketable heads of slow-growing varieties.

It is apparent that the diameter of Jersey Wakefield was influenced little by the time of year at which the variety was planted. Copenhagen Market, Glory and Succession produced smaller heads as the planting dates progressed from July to February. The heads of the slow-growing varieties, Premium Flat Dutch, and Penn State Ballhead, were reduced even more than the above by fall and winter plantings. Slow Bolting Flat Dutch which is well adapted for overwintering was not modified as greatly in head diameter as were the other two slow-growing varieties.

In 1944–45 the head diameter in the fall plantings of many of the varieties were somewhat smaller than in 1943–44. This may have been due in part to the effect of the cooler weather that winter in influencing the rate of nitrification in the soil and the absorption of nitrogen by the roots. No nitrogen was applied so some of the decrease in size could be laid to this factor. However, since Jersey Wakefield was not greatly affected it would appear that the nitrogen supply was not the most important factor. The plantings made from October to February matured in May, June and July. The high temperatures at that time tended to restrict frame growth and head development, the more so on the slower maturing varieties. In 1944 the total departure of the monthly means from the normal for April to July inclusive was —14.3 degrees F, while in 1945 it was only —2.8 degrees F. Thus the last plantings of 1944–45 matured under higher temperatures than did those of 1943–44. This tended to reduce head size.

Premature Seedstalk Development:—It has been shown by Boswell (1), Miller (4), and others that exposure to cool temperatures will cause premature seedstalk development of cabbage plants. Weather conditions differed somewhat in the two seasons under consideration. These resulted in different percentages of bolting from the same dates of planting (Table II). In 1944–45 plants of the August 1 seeding bolted more than in the previous year. This was particularly true of the slow-growing varieties. A comparison of the hours below 40 degrees F and above 70 degrees F during the fall and winter is given in Table III. This indicates that in the early fall of 1944 the plants from the August seeding had warmer conditions for growth than did those of the previous year and they were subsequently exposed to more hours of cold temperatures. Thus early growth was stimulated making the plants larger and so more susceptible later to the influence of the low winter temperatures. The use of 40 degrees F as a critical point does not mean that this is necessarily the critical temperature for seedstalk initiation. Different varieties might have different critical temperatures. It serves purely as a basis of comparison for the two seasons.

TABLE II—PERCENTAGE OF PLANTS FROM DIFFERENT SEEDING DATES WHICH BOLTED WITHOUT FORMING MARKETABLE HEADS

Variety	Jul 1 (Per Cent)	Jul 15 (Per Cent)	Aug 1 (Per Cent)	Aug 15 (Per Cent)	Sep 1 (Per Cent)	Sep 15 (Per Cent)	Oct 1 (Per Cent)	Oct 15 (Per Cent)	Nov 1 (Per Cent)	Dec 1 (Per Cent)	Jan 1 (Per Cent)	Jan 15 (Per Cent)	Feb 1 (Per Cent)
1943–44													
Jersey Wakefield	0	0	0	12	100	100	5	0	0	0	0	0	0
Copenhagen Market	0	0	0	8	100	100	100	82	69	*	0	2	0
Enkhuizen Glory	0	0	0	57	100	97	80	23	16	3	0	0	0
Succession	0	0	0	51	95	63	8	0	17	0	0	0	0
Slow Bolting Flat Dutch	0	6	2	90	55	26	3	0	0	0	0	0	0
Penn State Ballhead	0	0	3	100	52	46	0	0	3	0	0	0	0
Premium Late Flat Dutch	0	0	3	100	49	11	8	0	3	0	0	0	0
1944–45													
Jersey Wakefield	0	0	0	80	92	10	0	0	3	0	0	0	0
Copenhagen Market	0	0	8	97	100	100	32	24	50	3	0	3	0
Enkhiuzen Glory	0	0	0	78	95	51	12	17	6	0	0	0	0
Succession	0	3	12	93	66	8	0	0	0	3	6	16	6
Slow Bolting Flat Dutch	7	8	30	63	65	2	0	0	0	0	0	0	0
Penn State Ballhead	0	3	42	66	58	19	3	0	4	0	0	3	0
Premium Late Flat Dutch	11	8	36	92	43	0	0	0	0	0	0	0	0

*No planting.

There were marked differences between the varieties in the degree to which they bolted prematurely. In general the quicker growing the variety the greater was the bolting except for Jersey Wakefield and Slow Bolting Flat Dutch which apparently have some ability to withstand the effect of low temperature in causing premature seedstalk development.

TABLE III—HOURS BELOW 40 DEGREES F AND ABOVE 70 DEGREES F FOR THE PERIODS INDICATED

	1943–44		1944–45	
	Below 40 Degrees F (Hrs)	Above 70 Degrees F (Hrs)	Below 40 Degrees F (Hrs)	Above 70 Degrees F (Hrs)
Sep 1–15	——	156.0	——	211.0
Sep 16–30	——	156.0	——	147.5
Oct 1–15	——	122.0	——	113.5
Oct 16–31	2.5	35.5	——	106.0
Nov 1–15	52.5	42.0	0.5	——
Nov 16–30	64.0	——	67.5	——
Dec	133.5	——	198.5	——
Jan	164.0	——	201.5	——
Feb	80.0	——	89.5	——
Mar	59.0	83.5	138.5	——

SUMMARY

Of the varieties tested, Jersey Wakefield and Slow Bolting Flat Dutch offer the best possibilities for the production of heads in the lower Sacramento Valley during March and April.

The head diameter of Jersey Wakefield was not greatly modified by time of planting. In general the slower the rate of growth of a variety the more the head diameter was reduced as plantings progressed from July to February.

When plantings were made near the critical planting date for a given variety, the bolting was likely to be more severe in a quick-growing variety than in one making slower growth.

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The Relation of Rainfall, Soil Type and Replaceable Magnesium to Deficiency Symptoms

By J. B. Hester, G. E. Smith, and F. A. Shelton,
Riverton, N. J.

Magnesium has been known to be a constituent of chlorophyl since 1906 (10) and the role of this element in the nutrition of green plants has been the subject of considerable research (2). Upward of a thousand reports have been issued on the subject of magnesium in agriculture and approximately 125 cases (2) of deficiencies recorded. For the most part, the deficiencies reported in the United States occur on the more sandy types of soil in the Coastal Plain section.

The chlorotic condition of the leaves of agronomic plants caused by insufficient magnesium has been well described (8) and need not be repeated here. However, plants vary in the amount (3) of magnesium in the leaves that show deficiency symptoms and of course, the larger the growth made, the more magnesium is required to produce healthy plants. For the most part vigorously growing plants that have a large leaf surface are likely to show deficiency symptoms first, but the amount of other available nutrients in the soil influences the ability of the plant to absorb sufficient magnesium. The perçentage of calcium in plants is usually higher than magnesium because of the larger amount of available calcium in the soil and because a greater force exists between the soil clay and the magnesium ion than between the calcium ion and the soil clay particle. The amount of potassium in the plant is higher than magnesium because the force between the soil colloid and potassium is less than magnesium and clay. Magnesium is a much weaker ion, in the terms of thermodynamics, than either potassium or calcium and therefore is not as readily absorbed by the plant. In fact, under certain conditions, the quantity of available potassium and calcium in the soil may have more influence on the absorption of magnesium by the plant than the amount of available magnesium. This was shown by the prevalence of magnesium deficiency in the sweet potato fields in New Jersey in 1946 that had been heavily fertilized with potash; that is, there was more magnesium deficiency on the soils heavily fertilized with potash than on those less heavily fertilized. However, it must not be overlooked that the soils were poorly supplied with available magnesium.

Intensity Factor of Ions

Confirming the importance of the intensity phenomenon observed by Cooper, *et al.* (4) of the removal of metallic ions from the soil and their absorption by the plants, data, published elsewhere (7) on the composition of tomatoes, manure, and commercial fertilizer, are given in Table I. These data are arranged according to the intensity of activity of the ions. Good agreement is shown between the intensity of activity of the ions and the amount of metallic nutrients in the plant material. The high iron and manganese content in the manure is probably due to introduction of soil from the hoof of animals.

TABLE I—ARRANGEMENT OF METALLIC NUTRIENTS FOUND IN TOMATOES, MANURE, AND COMMERCIAL FERTILIZER IN ORDER OF ION STRENGTH

Materials	Pounds						
	K	Ca	Mg	Mn	Zn	Fe	Cu
12½ tons Tomatoes	164	91	15	0.65	0.12	0.47	0.08
10 tons Manure	82	46	12	6.00	—	15.00	0.07
½ ton Commercial fertilizer	42	118	7	0.22	0.96	6.30	0.03

These data bring out the fact that commercial fertilizers, as a whole, have introduced large amounts of calcium and potassium, but smaller amounts of magnesium. They also introduce large amounts of sulfur, chlorides and nitrogen which, when leached from the soil, carry metallic ions. Thus, the introduction of fertilizers increases the depletion of magnesium both from the standpoint of leaching and of absorption due to greater growth of plants.

Before leaving this subject, the mass action effect of ions should be mentioned. Soils that have large amounts of available calcium and potassium in proportion to small amounts of magnesium, tend to depress the amount of magnesium (1, 5, 6) that the plant absorbs from the soil because of the superior number of ions. The total quantity of ions, calcium, magnesium, potassium, and sodium, tend to be constant in the plant, but one or the other may replace an equivalent amount of another ion.

DIFFERENT TYPES OF CLAYS

Soils in the Coastal Plain of the United States have less available magnesium than soils from certain other areas. Data given in Table II point out that the typical Coastal Plain soils (Collington, Freehold,

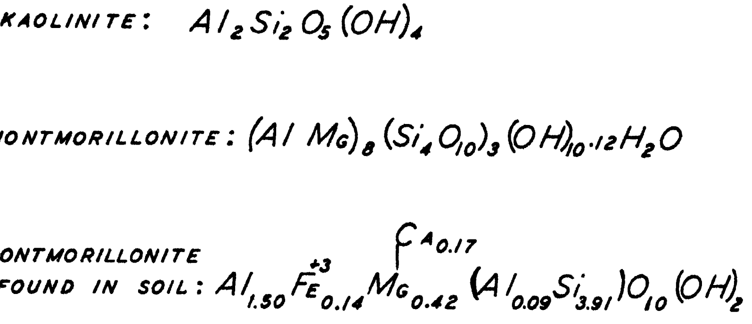
TABLE II—THE REPLACEABLE MAGNESIUM IN VARIOUS NEW JERSEY VIRGIN SOILS AS COMPARED TO OTHER SOILS*

Soil Type	Location	pH	Organic Matter (Per Cent)	Magnesium (Pounds Per Acre)
Collington sand	Hainesport, N. J.	4.7	0.5	53
Freehold fine sand	Moorestown, N. J.	4.3	2.5	77
Collington sandy loam	Mt. Laurel, N. J.	5.1	2.1	182
Sassafras sandy loam	Moorestown, N. J.	4.6	3.4	89
Bladen sandy loam	Norfolk, Va.	4.4	1.8	132
Elkton sandy loam	Moorestown, N. J.	4.6	2.1	209
Portsmouth sandy loam	Lenola, N. J.	3.9	14.4	199
Portsmouth sandy loam	Norfolk, Va.	4.1	13.5	211
Freneau sandy loam	Vincentown, N. J.	4.7	17.7	281
Lansdale silt loam	Rocktown, N. J.	5.2	4.2	185
Penn silt loam	Flemington, N. J.	4.9	3.9	197
Toledo silty clay loam	Toledo, Ohio	7.1	10.5	262
Black clay loam	Des Plaines, Ill.	6.9	9.6	228
Brookston clay loam	Chatham, Canada	6.6	8.7	218
Brookston silty clay loam	Comber, Canada	6.9	9.2	199
Chestnut brown sandy loam	Colborne, Canada	7.2	5.3	197
Brown sandy loam	Toronto, Canada	6.3	4.7	206
Tifton sandy loam	Meigs, Ga.	5.0	2.7	77
Norfolk sandy loam	Norfolk, Va.	5.0	1.0	111
Norfolk sandy loam	Cairo, Ga.	5.0	1.7	80
Red Bay sandy loam	Western Florida	6.4	2.2	170
Blakely sandy loam	Western Florida	5.8	1.0	146

*Soils all analyzed by the author on a comparable basis using neutral ammonium acetate and chloride for extracting.

Sassafras, Bladen, Elkton, Portsmouth, Tifton, Norfolk) are lower in replaceable magnesium than the heavier types of soil that are not from the Coastal Plain.

The clay in Coastal Plain soils is of the kaolinitic type which does not carry magnesium as a normal constituent. The montmorillonite type clay (9) found in many other soils carries magnesium as a normal constituent; Fig. 1 brings this out. Therefore, soils of the latter type are less likely to show a low available magnesium content. From the above discussion it is shown that magnesium nutrition is an important problem on Coastal Plain soils.



KAOLINITE: $Al_2Si_2O_5(OH)_4$

MONTMORILLONITE: $(Al\ Mg)_8(Si_4O_{10})_3(OH)_{10}\cdot 12H_2O$

MONTMORILLONITE FOUND IN SOIL: $Al_{1.50}Fe^{+3}_{0.14}\overset{Ca_{0.17}}{Mg_{0.42}}(Al_{0.09}Si_{3.91})O_{10}(OH)_2$

FIG. 1. Composition of types of clay.

MAGNESIUM DEFICIENCY IN 1946

Magnesium deficiency was very prevalent in the Coastal Plain section of New Jersey in 1946. Several thousand acres of tomatoes (estimated between 3,000 and 4,000 acres) suffered with various degrees of deficiency from practically complete crop failure to mild injury. Many fields were saved by the application of soluble forms of magnesium after the deficiency was first observed. Other crops were also influenced by the deficiency, particularly soy beans, sweet potatoes, and sweet corn. Because of the deficiency symptoms observed early in the season, a study was made of soil on which magnesium deficient tomatoes were growing. These data are shown in Table III. These

TABLE III—SOIL FACTORS IN MAGNESIUM DEFICIENT AND ADJACENT NON-DEFICIENT SOILS

Soils*	No. Fields	Sand (Per Cent)	Silt (Per Cent)	Clay (Per Cent)	Organic Matter (Per Cent)	Mean pH	Pounds Per Acre Replaceable	
							Ca	Mg
Deficient	15	78	12	10	1.54	5.19	534	78
Average Deviation	—	5	4	2	0.32	0.26	27	11
Non-deficient	16	80	11	9	1.32	5.74	885	132
Average Deviation	—	5	3	2	0.30	0.22	194	28

*All of these fields had an average of about 1,500 pounds of a 5–10–10 commercial fertilizer mixture per acre.

analyses show that the deficiency occurred on sandy soils, the clay content being close to 10 per cent and the silt 12 per cent. The total organic matter content was approximately 1.5 per cent and the pH value below 6.0. The soils that showed the deficiency were about 0.5 of a unit more acid than adjoining similar soils on which the deficiency did not develop. The difference in the pH value of the soil also correlates with the differences in replaceable calcium and magnesium content. The deficient soils had about 534 pounds of replaceable calcium per acre and 78 pounds of magnesium while the non-deficient soils had 885 and 132 pounds respectively for calcium and magnesium. In other words, plants growing on soils that have less than 100 pounds of replaceable magnesium per acre are likely to show magnesium deficiency. Two hundred pounds of magnesium sulfate per acre stopped the deficiency from developing. Since magnesium deficiency is not as prevalent every year as in 1946, the weather must have had something to do with it.

RAINFALL AND LEACHING IN 1946

A leaching experiment was being conducted near Riverton, New Jersey on three distinct soil types, an Evesboro sand, a Woodstown sandy loam, and a Sassafras loam with a clay subsoil. This experiment consisted of sinking 12-inch deep board frames 10 feet square about 6 inches in the soil and leaving 6 inches above the surface. The soil was kept clean cultivated throughout the season. On April 9th the soil in one frame was sprayed with a solution of 500 grams of potassium chloride and each month thereafter the soil was sampled from the 0 to 9 and 9 to 18 inch depths. The results of the analyses of the soil for chlorides and the weekly accumulation of rainfall are shown in Fig. 2. These data show that, during the heavy rainfall the latter

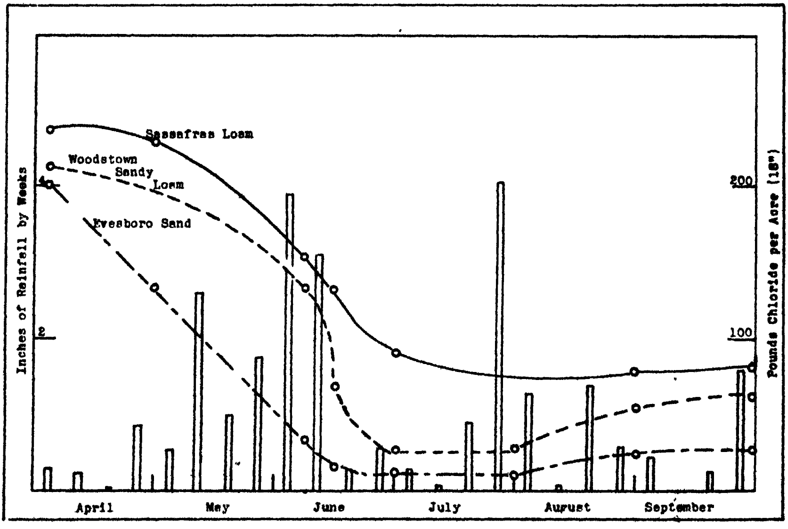


FIG. 2. Leaching of chlorides through 18 inches of soil.

part of May and the early part of June, most of the chlorides moved below the 18 inch depth of the sand and sandy loam soil. However, not as much leached in the heavy soil.

Since the chloride ion moved out of the soil, it is reasonable to believe that the other soluble ions leached also. Undoubtedly the soluble magnesium leached from the sands and sandy loam soils and, for this reason, the equilibrium between the replaceable magnesium and the water soluble or plant available magnesium could not be reestablished sufficiently rapid to supply the plants' need. Because of the relative intensity of the activity of the potassium, calcium and magnesium ions, as shown before, the plants first developed magnesium deficiency. Furthermore, extreme magnesium deficiency is not likely to develop on soils similar to the ones above-mentioned except under conditions of high rainfall, heavy potash fertilization, and low magnesium content. Where available magnesium is known to be low in the soil, as shown by soil analyses, available sources of magnesium should be added before the crop is planted.

SUMMARY

Magnesium deficiency was prevalent in New Jersey in tomato and sweet potato fields in 1946. The deficiency was observed on sandy soils that had less than 100 pounds of replaceable magnesium per acre and did not occur on those that averaged 132 or more pounds per acre. Magnesuim sulfate, at the rate of 200 pounds per acre, prevented the deficiency from developing even after it became prevalent in the field. All soils analyzing low in magnesium should be limed with a dolomitic liming material or have approximately 2 per cent of available magnesium in the commercial fertilizer mixture.

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The Use of Growth-Regulating Substances in the Propagation of Cabbage from Cuttings[1]

By P. H. HEINZE, *U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.*

THE practice of propagating cabbage from cuttings is not new. Isbell (1, 2, 3) has shown how different types of cuttings may aid in overcoming some of the difficulties of increasing cabbage breeding stock and carrying it from season to season. One of the problems that arose at the United States Regional Vegetable Breeding Laboratory at Charleston, South Carolina was the maintenance and propagation of individual heads selected from the spring crops. After the heads were harvested and examined for the various factors upon which selection was based, the usual practice was to save the stumps from which the heads were cut and produce seed therefrom. The long, warm summers and the incidence of disease prohibited keeping these stumps without cold storage; and when given cold storage a large percentage of the stumps never revived with the advent of cooler, more favorable weather. In this paper techniques are described for making cuttings and for using growth-regulating substances that have proven helpful in the propagation of certain valuable cabbage breeding stocks.

MATERIALS

The cabbage heads were harvested, brought into the laboratory, cut in halves, and examined for various horticultural characteristics and vitamin C content. The remaining portions of the selected heads were cut again forming pieces representing approximately a quarter of the original head. The individual leaves were removed from these quarters by cutting a small portion of the core with each leaf, leaving the axillary bud intact (Fig. 1, A). From 20 to 30 cuttings were usually obtained from each head. These cuttings were used to test the effectiveness of indolebutyric acid and a-naphthaleneacetic acid as aids in propagation. Various concentrations of these substances in solutions and also in dusts, with the fungicides Fermate, Arasan, and Spergon as carriers, were applied to the cuttings from numerous selected heads in the fall of 1945 and spring of 1946.

METHODS AND RESULTS

Cuttings from heads of cabbage were divided into various lots and tied into small bundles with all of the core cut surfaces at one end of the bundle. The untreated checks or control lots were always planted in a sand bench immediately after the cuttings had been made. Solutions of a-naphthaleneacetic acid and indolebutyric acid were used for treatments in the first two experiments. The acids were dissolved in a

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[1] The author wishes to acknowledge the assistance of Miss Clara Auld and Miss Charlotte Gaetjens in the preparation of the cuttings and in the recording of the data.

few drops of ethyl alcohol then diluted to the desired concentration with distilled water. The solutions were poured into trays and the cuttings placed in the solutions with about 1 inch of the core ends submerged. The cuttings were allowed to stand in the solutions over night, 16 hours, and were then removed and planted immediately in a sand bench. Two weeks later they were removed from the sand and a record was made of the number of cuttings rooted, the average length of the roots, and the number of roots per rooted cutting. The rooted cuttings were then transplanted into composted soil in 4-inch pots and allowed to develop into plants (Fig. 1, B and C).

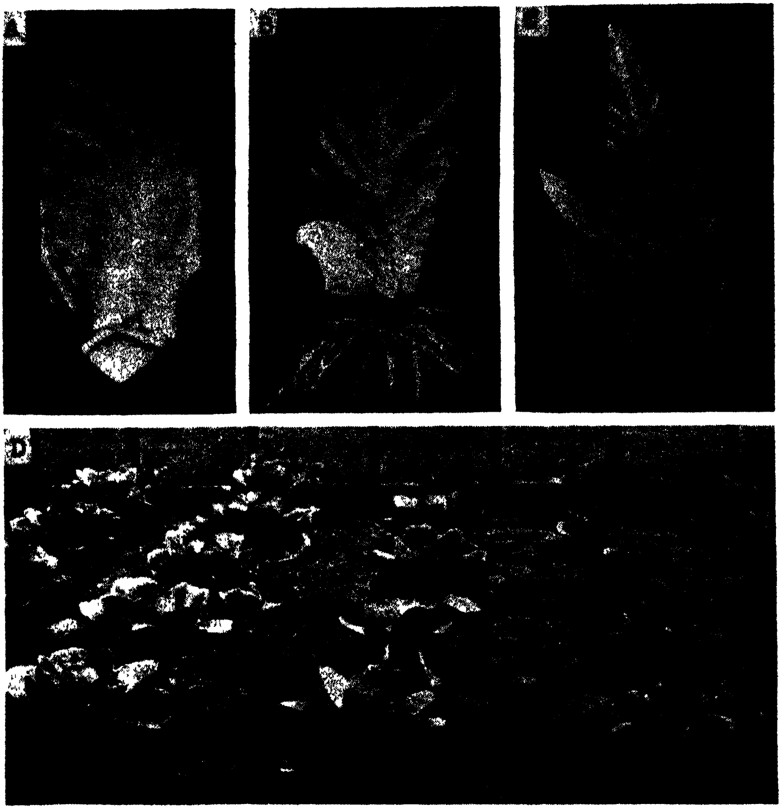

FIG. 1. A, freshly made cutting showing a portion of the core and the axillary bud. B, cutting after being in the sand bench 2 weeks. C, plant 5 weeks after cutting was made. D, plants 80 days after cuttings were made.

In the first experiment the cuttings from each of ten heads were divided into four evenly matched lots. One lot from each head was used as a control. One of the three remaining lots from each of five heads was placed into a naphthaleneacetic acid solution at a concentration of 20 parts per million. Another lot from these heads was placed in a solution of 40 parts per million and the last lot in a solution of 80 parts per million. In this manner a portion of each head was represented in each of the three treatments and the control. Three lots of cuttings from the other five heads were similarly treated with indolebutyric acid solutions of 20, 40, and 80 parts per million concentration for 16 hours.

In the second experiment cuttings from each of four heads were divided into five lots for the following treatments: control, 5, 10, 20, and 40 parts per million of naphthaleneacetic acid in solution. Cuttings from each of three other heads were divided into five lots and treated with indolebutyric acid solutions of the same concentrations as in the case of naphthaleneacetic acid. All cuttings except the controls were kept in the solutions for 16 hours, then planted in a sand bench.

The first experiment showed that the treated cuttings rooted much more rapidly and profusely than the untreated cuttings (Fig. 2). There was no appreciable difference between the lots receiving 20 or 40 parts per million of naphthaleneacetic acid, but those receiving 80 parts per million showed definite injury. Many of the roots were gnarled and very short, and others were very thin and hairlike in appearance. This was the only treatment in these experiments that produced roots with an abnormal appearance. All of the naphthaleneacetic acid treatments and the indolebutyric acid treatments of 40 and 80 parts per million produced from 97 to 100 per cent rooted cuttings. The lots receiving 20 parts per million of indolebutyric acid had 77 per cent rooted cuttings, in comparison with 47 per cent for the controls. The lots receiv-

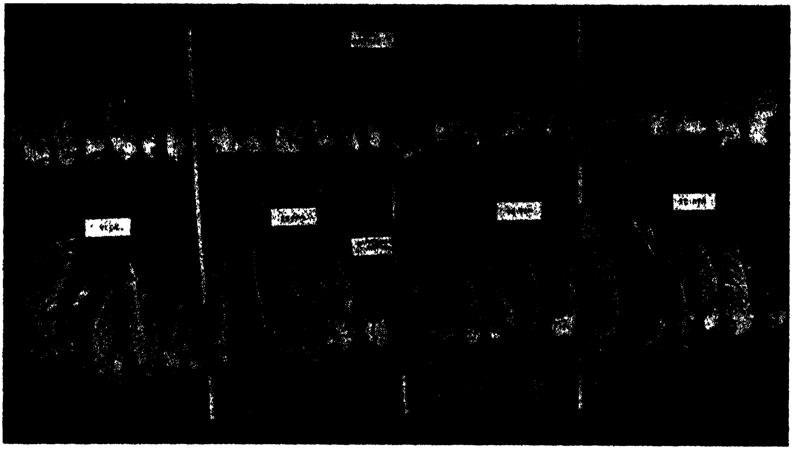

FIG. 2. The effects of various concentrations of indolebutyric acid and naphthaleneacetic acid on the rooting response of cabbage cuttings. The cuttings from these two heads were treated for 16 hours in solutions of the growth substances and kept in a sand bench 2 weeks before photographing. Top row, indolebutyric acid; bottom row, naphthaleneacetic acid. Columns, left to right: control, 20 parts per million, 40 parts per million, and 80 parts per million.

ing 20 parts per million of indolebutyric acid also had fewer roots, averaging 10.7, than the other treated cuttings, 12.8, but had considerably more than the controls, 3.9. There was no marked difference between lots in the average length of the roots except that those receiving 80 parts per million of naphthaleneacetic acid were considerably shorter.

In the second experiment the cuttings treated with 20 parts per million of naphthaleneacetic acid gave the highest percentage, 96, of rooted cuttings. The 10, 40, and 5 parts per million solutions in the naphthaleneactic acid treatments gave 94, 80, and 77 per cent rooted cuttings, respectively, in comparison with 37 per cent for the controls. The lots receiving 20 parts per million of naphthaleneacetic acid also had the greatest number of roots per cutting, 12.6, in comparison with 10.7 for the 10 parts per million concentration and 3.8 for the controls. In the indolebutyric acid treatments the percentage of rooted cuttings progressively increased with increased concentration of the solution. The 5 parts per million treatment gave the same percentage, 37, of rooted cuttings as the controls. The 10 parts per million treatment gave 44 per cent; 20 parts per million, 88 per cent; and 40 parts per million, 94 per cent. The longest roots and the largest number per rooted cutting in the lots treated with indolebutyric acid were found in those receiving 40 parts per million. Here, as in experiment 1, the cuttings receiving 40 parts per million of indolebutyric acid gave about the same response as those receiving 20 parts per million of naphthaleneacetic acid.

While experiments 1 and 2 were being carried out a number of other heads were selected for propagation. About one-third of the heads were chosen as controls and the cuttings from the others were treated over night in a solution of 20 parts per million of indolebutyric acid. Although the results of experiments 1 and 2 showed that 20 parts per million of indolebutyric acid was not the best treatment, the treated cuttings from these heads showed a superior rooting response over the controls. Of the 193 control cuttings 73 rooted in 2 weeks, while 345 of the 444 treated cuttings rooted. The treated cuttings that rooted had a greater number of roots per cutting, 5.3, than the untreated, 3.2. The untreated cuttings that had not rooted were returned to the sand bench and taken up 2 weeks later, 4 weeks after the cuttings were made. After 4 weeks 54 per cent of the total number of untreated cuttings had rooted, whereas 78 per cent of the treated cuttings had rooted after being in the sand bench only 2 weeks. Table I summarizes the data obtained from all experiments in which solutions of growth substances were used for treating the cuttings.

Naphthaleneacetic acid and indolebutyric acid were prepared in mixtures with Fermate, Arasan, and Spergon. The acids were dissolved in a small quantity of ethyl alcohol then mixed with the fungicide carrier in a mortar. The alcohol was evaporated by warming the mixture slightly. The mixture was then passed through a 60-mesh screen in order to produce a fluffy dust. Fermate and Arasan containing 0.05 per cent (0.5 parts per thousand), 0.10 per cent, and 0.15 per cent of the growth substances were prepared. Spergon was used

TABLE I—ROOTING RESPONSES OF CABBAGE CUTTINGS TREATED FOR 16 HOURS IN SOLUTIONS OF VARIOUS CONCENTRATIONS OF A-NAPHTHALENEACETIC ACID AND INDOLEBUTYRIC ACID

	Control	5 Ppm	10 Ppm	20 Ppm	40 Ppm	80 Ppm
A-Naphthaleneacetic Acid						
Number of cuttings	224.0	26.0	235.0	156.0	62.0	31.0
Number of cuttings rooted	84.0	20.0	221.0	141 0	53.0	31.0
Percentage of cuttings rooted	38.0	77.0	94.0	90.0	85.0	100.0
Number of roots per rooted cutting	3.1	12.4	11.1	13.1	11.2	12.3
Average length of roots (centimeters)	3.8	4.6	5.0	5.2	5.3	3.2
Indolebutyric Acid						
Number of cuttings	289 0	16.0	219.0	658.0	46.0	30.0
Number of cuttings rooted	98.0	6.0	173.0	528.0	44.0	30.0
Percentage of cuttings rooted	34.0	38.0	79.0	80.0	96.0	100.0
Number of roots per rooted cutting	3.1	—	8.1	7.8	12.9	14.8
Average length of roots (centimeters)	3.9	—	4.1	4.9	6 9	5.9

with only one concentration, 0.1 per cent, of the growth substances. The cuttings were placed in a paper bag or tight can and shaken with a sufficient quantity of the several mixtures of fungicide and growth substance to coat the cuttings thoroughly. The cuttings were planted immediately in a sand bench and removed 2 weeks later for examination. The data in Table II show that all of the treated cuttings were superior to the control cuttings in rooting. The cuttings treated with Spergon appeared to root well but the growth of the roots was inhibited. Since very little trouble is experienced with the cuttings rotting in the sand bench in cooler weather, no data on the fungicidal action of the carriers could be determined with the cuttings made in the fall. In the spring of 1946 approximately 60 heads were selected

TABLE II—ROOTING RESPONSES OF CABBAGE CUTTINGS DUSTED WITH FUNGICIDES CONTAINING A-NAPHTHALENEACETIC ACID AND INDOLEBUTYRIC ACID IN THREE CONCENTRATIONS (FALL 1945)

	Control	A-Naphthaleneacetic (Per Cent)			Indolebutyric (Per Cent)		
		0.05	0.10	0.15	0.05	0.10	0.15
Arasan							
Number of cuttings	96.0	57.0	59.0	42.0	44.0	49.0	58.0
Number of cuttings rooted	41.0	45.0	51.0	35.0	30.0	43.0	52.0
Percentage of cuttings rooted	43.0	79.0	86.0	83.0	68.0	88 0	90.0
Number of roots per rooted cutting	4.3	4.7	5.5	6.8	5.5	5.3	5.3
Average length of roots (centimeters)	4.5	3.6	4.2	5.2	4.5	5.3	5.8
Fermate							
Number of cuttings	59.0	29.0	29.0	29.0	30.0	30.0	30.0
Number of cuttings rooted	27.0	27.0	28.0	29.0	19.0	26.0	28 0
Percentage of cuttings rooted	46.0	93.0	97.0	100.0	63.0	87.0	93.0
Number of roots per rooted cutting	4.0	7.3	9.4	11.1	3.6	4.9	8.7
Average length of roots (centimeters)	4.0	5.8	5.5	5.5	4.5	5.1	6.1
Spergon							
Number of cuttings	77.0	—	63 0	—	—	63.0	—
Number of cuttings rooted	44.0	—	58 0	—	—	57.0	—
Percentage of cuttings rooted	57.0	—	92.0	—	—	90.0	—
Number of roots per rooted cutting	3.7	—	6.6	—	—	5.9	—
Average length of roots (centimeters)	3.3	—	2.7	—	—	3.9	—

for propagation and divided into three lots. The cuttings from one lot were dusted with Arasan containing 0.10 per cent of naphthaleneacetic acid, another lot was dusted with Fermate containing 0.10 per cent of naphthaleneacetic acid, and the third lot was used as a control. Twenty-nine per cent of the controls, 31 per cent of the Arasan-treated cuttings, and 53 per cent of the Fermate-treated cuttings rooted. McClellan and Stuart (4) found that combinations of naphthaleneacetic or indolebutyric acid with various fungicides produced heavy rooting and afforded very good protection from certain rot-producing organisms when applied to Easter lily bulb scales. No evidence of high disease protection from the use of fungicides was obtained with cabbage cuttings in the present tests. Thirty per cent of the controls, 46 per cent of the Arasan-treated cuttings, and 26 per cent of the Fermate-treated ones were rotted after 2 weeks in the sand bench.

SUMMARY

In the cabbage breeding program of the United States Regional Vegetable Breeding Laboratory the selection of heads from the spring crop is of particularly importance in the establishment of non-bolting lines. Cuttings from these selected heads can be rooted and kept growing through the summer, and seed produced the following spring.

It has been found advantageous to use naphthaleneacetic acid and indolebutyric acid as aids in inducing rooting in the cuttings. The most favorable responses were obtained by treating the cuttings over night (16 hours) in solutions containing either 20 to 40 parts per million of naphthaleneacetic acid or 40 to 80 parts per million of indolebutyric acid before placing them in the sand bench. Responses were measured by the percentage of the cuttings that rooted within 2 weeks after treatment and the number and length of the roots that were produced on the rooted cuttings.

Application of growth substances in the dust form with fungicides as carriers has its advantages in the saving of time and in the ease of handling. The most satisfactory rooting of the dust-treated cabbage cuttings was obtained by using 0.10 to 0.15 per cent of naphthaleneacetic acid in Fermate. Fermate gave only a very slight indication of affording any protection from rot-producing organisms.

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Effect of Some Growth Regulators on Yield of Bush Lima Beans

By F. E. WESTER and PAUL C. MARTH, *U. S. Department of Agriculture, Beltsville, Md.*

EXCESSIVE drop of blossoms and small pods of lima beans is responsible for reduced yields. Such losses are usually greater during periods of hot dry weather.

Since plant-growth regulators, especially alpha-naphthaleneacetic acid, increases the final yield of picked apples by preventing the apples from abscising before they reach maturity, as reported by Gardner, Marth and Batjer (2, 3) it was decided to determine if this growth regulator would have the same effect on pods of lima beans. Fisher (1) and Murneek (4) have reported reduction in the bud, blossom, and pod drop of canning string beans by application of sprays or dust mixtures of growth regulators.

This paper presents the results of studies with growth regulators on yield of fresh marketable pods in bush lima beans.

MATERIALS AND METHODS

Three separate experiments were conducted on effect of growth regulators on yield of bush lima beans in the field at Beltsville, Maryland, in 1946.

In all three experiments, three seeds were planted in light sandy soil on June 11, in hills spaced 1 foot apart in rows spaced 3 feet apart. After the plants were up, each hill was thinned to one plant.

Two harvests of fresh marketable pods were made from each experiment at which time the pods were counted and weighed. The data were analyzed by analysis of variance.

Experiment 1 consisted of eight growth regulator treatments on Fordhook bush lima beans. The treatments were replicated four times. Forty-two hills were included in each treatment in each replicate.

The eight treatments used in experiment 1 were as follows:

1. Control
2. 0.1 per cent alpha-naphthaleneacetic acid in talc dust
3. 0.2 per cent alpha-naphthaleneacetic acid in talc dust
4. 0.001 per cent alpha-naphthaleneacetic acid spray, in 0.5 per cent Carbowax 1500
5. 0.005 per cent alpha-naphthaleneacetic acid spray, in 0.5 per cent Carbowax 1500
6. 0.5 per cent alpha-naphthaleneacetic acid spray, in 0.5 per cent Carbowax 1500
7. 0.005 per cent alpha-naphthaleneacetic acid spray, in 0.5 per cent Carbowax 1500 with ½ ppm of boron
8. 0.01 per cent of calcium salt of alpha-naphthaleneacetic acid applied as a spray

The same 1-quart-capacity hand dusters was used for both applications, the lower concentration being applied first. The sprays were applied by means of a 1-quart-capacity hand pressure sprayer in the same manner as the dusts with the exception that a separate sprayer was used for applying treatments containing boron or the calcium salt of alpha-naphthaleneacetic acid. As each plant was dusted or sprayed a piece of cardboard was held partly around it to reduce the movement of the dust or sprays to neighboring plants.

The first application of growth regulators in experiment 1 was made on July 22, 1 week before the plants were ready to come into bloom. A heavy rain occurred soon after the treatments were applied. A second application was made on July 26th, 4 hours following a light shower. Further rain did not occur until August 1. The third and final application was made on August 14th. Five-hundredths of an inch of rain fell on August 16th and .25 of an inch fell on August 17th. On August 14th the plants were still blooming profusely and had set many small pods. First harvest was made on September 12th and second harvest on September 26th.

Experiment 2 was on the effect of low to high concentrations of alpha-naphthaleneacetic acid dust mixture on the yield of fresh marketable pods of Fordhook bush lima beans. The concentrations used were 5, 50, 100 and 1000 ppm respectively. Thirty-two plants were used for each plot, with replication in three blocks.

The first dust application was made on August 13th when the plants were in full bloom with small pods starting to set. Five-hundredths of an inch of rain fell August 16th and .25 of an inch of rain fell on August 17th. The second dusting was made on August 23rd following a heavy rain. Rain did not again occur until August 30th.

The dust was applied with the same hand duster and in the same manner and at the same time of day as in Experiment 1. The first harvest was made on September 16th and the second and final harvest was made on September 26th.

Experiment 3 was a study on the effect of 50 ppm of alpha-naphthaleneacetic acid dust mixture on the yield of 13 bush varieties of lima beans.

The 13 varieties of bush lima beans were as follows:

1. Burpee's Improved Bush
2. Early Market
3. Regular Fordhook
4. Concentrated Fordhook
5. Fordhook 242
6. Clark's Bush
7. Henderson
8. Peerless
9. U. S. 343
10. U. S. 403A
11. Maryland selection No. 5622
12. Maryland selection No. 5643
13. Thorogreen

Thirty-two plants of each variety were grown in each of four replicates. In the first and third replicates, the first 16 plants were dusted with 50 ppm of alpha-naphthaleneacetic acid. In the second and fourth replications the last 16 plants were dusted with the growth regulator.

The dust was applied by means of a Dobbins hand dusting machine. The first dusting was on August 2nd when the plants were starting to bloom. Eight-hundredths of an inch of rain fell 4 days later. The second dusting was on August 13th with the plants in full bloom and with many small pods setting. Five-hundredths of an inch of rain fell 3 days later.

On each date the dust was applied in the morning slightly after 8 a. m. when the dew was still on the leaves.

The first harvest was made on September 9th and the second harvest was made on September 19th.

Discussion of Results

The temperature at blooming and setting periods was not so high as in past seasons. This resulted in an excellent set of pods on the majority of other lima bean varieties and selections that were grown at Beltsville, in 1946, but which are not included in the experiments reported in this paper.

Table I summarizes the results of experiment 1. In this table analysis of variance showed a significant difference at the 5 per cent point only in pod number and pod weight at first harvest and in pod weight at second harvest due to treatment. There was no significant difference in pod number for second and total harvests. Neither was there a significant difference in pod weight for total harvests.

TABLE I—Effect of Growth Regulator Sprays and Dusts on Yield of Fresh Marketable Fordhook Bush Lima Beans (Weight in Grams)

Growth Regulator	Total Plants (No)	Pods First Harvest		Pods Second Harvest		Pods, Total Harvests	
		(No)	(Gms)	(No)	(Gms)	(No)	(Gms)
Control	156	862	8,644	2,375	27,454	3,237	36,098
0.1 per cent NAC* in talc dust	149	669	11,010	2,036	26,177	2,705	37,187
0.2 per cent NAC in talc dust	158	439	5,774	2,579	32,849	3,018	38,623
0.001 per cent NAC spray**	159	786	10,464	2,716	34,493	3,502	44,957
0.005 per cent NAC spray**	153	948	10,320	2,205	24,306	3,153	34,626
0.5 per cent NAC spray**	155	642	8,186	1,902	22,948	2,544	31,134
0.005 per cent NAC spray†	159	1,094	13,931	2,343	30,045	3,437	43,976
0.01 per cent of Ca salt of NAC	161	488	6,846	2,725	31,455	3,213	38,301
L.S.D. at 5 per cent point	—	225	3,791	1,660	5,980	1,302	14,150

*Alpha-naphthaleneacetic acid.
**Prepared in 0.5 per cent Carbowax 1500.
†Prepared in 0.5 per cent Carbowax 1500 to which ½ ppm of boron was added.

The addition of ½ ppm of boron to sprays containing 0.005 per cent concentration of alpha-naphthaleneacetic acid caused a significant increase in pod setting and total weight produced in the first harvest in comparison with the control plants, but these plants at the later picking and in total yield failed to show a significant increase in yield due to this treatment. There was a significant decrease at the 5 per cent point at first harvest in pod number due to 0.2 per cent alpha-naphthaleneacetic acid in dust and 0.01 per cent of the calcium salt of alpha-naphthaleneacetic acid spray but these treatments caused no significant difference in pod weight. Second and total harvests of these treatments showed no significant difference in yield.

It is of interest that foliar color differences were noted in plants treated with the 0.5 per cent spray concentration and 0.2 per cent dust mixture of alpha-naphthaleneacetic acid. All plants in each of these treatments developed an intense green coloration within 10 days after treatment in comparison with the controls and plants of the other treatments the foliage of which was of the usual light yellowish green color. Aside from the foliage coloring effect, no other plant growth response, such as injury or epinasty, was observed.

In Table II the data on pod number and pod weight of fresh marketable pods at first, second, and both harvests of Fordhook bush lima beans are summarized for experiment 2. Analysis of variance showed

TABLE II—EFFECT OF RELATIVELY LOW TO HIGH CONCENTRATIONS OF A-NAPHTHALENEACETIC ACID DUSTS MIXTURE ON YIELD OF FRESH MARKETABLE PODS OF LIMA BEANS FOR THE FIRST, SECOND, AND TOTAL HARVESTS (WEIGHT IN GRAMS)

Concentration of Alpha-Naphthaleneacetic Acid (Parts Per Million)	Total Plants (No)	Pods, First Harvest		Pods, Second Harvest		Pods, Total Harvests	
		(No)	(Gms)	(No)	(Gms)	(No)	(Gms)
Check	89	1,098	14,030	803	8,247	1,901	22,277
5	90	954	10,842	844	8,932	1,798	19,774
50	90	1,035	12,805	779	7,779	1,814	20,584
100	90	1,145	14,134	759	9,160	1,904	23,294
200	87	799	10,352	1,138	12,796	1,937	23,148
1,000	80	940	12,094	756	8,455	1,696	20,549
L.S.D. at 5 per cent point	—	158	1,926	223	4,260	252	3,645

TABLE III—EFFECT OF TALC DUST APPLICATION CONTAINING 50 PARTS PER MILLION OF ALPHA-NAPHTHALENEACETIC ACID ON YIELD OF FRESH MARKETABLE PODS IN THIRTEEN VARIETIES OF BUSH LIMA BEANS (WEIGHT IN GRAMS)

Variety	Total Plants		Total Yield for Two Harvests: Pod Number*		Total Yield for Two Harvests: Pod Weight**	
	Check (No)	Treated (No)	Check (No)	Treated (No)	Check (Gms)	Treated (Gms)
Burpee's Improved Bush	61	62	849	588	8,807	5,623
Early Market	63	64	1,503	1,281	11,380	10,007
Regular Fordhook	63	64	1,163	1,179	12,924	13,663
Concentrated Fordhook	62	64	1,334	1,439	12,541	11,367
Fordhook 242	62	64	1,472	1,344	13,389	13,194
Clark's bush	64	62	2,534	2,821	8,893	9,112
Henderson	64	63	2,530	2,506	8,793	8,538
U. S. 403A	61	64	2,645	2,439	8,434	8,123
Peerless	62	63	1,853	1,759	11,950	11,324
U. S. 343	62	64	1,815	1,914	6,222	6,674
Md. selection No. 5622	64	62	2,384	2,407	11,036	11,134
Md. selection No. 5643	64	63	3,367	3,143	13,027	11,686
Thorogreen	58	61	3,169	2,768	10,293	9,356
L.S.D. at 5 per cent point between varieties	—	—	308	308	1,646	1,646
L.S.D. at 1 per cent point between varieties	—	—	404	404	2,150	2,150

*L.S.D. at 5 per cent point between treatments = 580.

**L.S.D. at 5 per cent point between treatments = 3,892.

no significant increase in yield over controls due to growth regulators except at 200 ppm of alpha-naphthaleneacetic acid dust at second harvest. This increase compensates for the significant decrease at first harvest. For total harvest there was no significant difference in pod number or pod weight. None of the treatments appeared to have any detrimental or beneficial growth effects on the plants.

Table III gives the total pod number and pod weight of fresh marketable pods in 13 varieties of bush lima beans treated with 50 ppm of alpha-naphthaleneacetic acid dust mixture for experiment 3. Analysis of variance of these data showed no significant difference in yield due to treatment but there was a significant difference due to variety. Analysis of variance of data for first and second harvests considered separately also showed no significant difference due to treatment, but a significant difference was obtained between varieties.

SUMMARY

Under the conditions of these experiments the application of alpha-naphthaleneacetic acid in spray or dust at various concentrations had no significant effect on total yield of fresh marketable pods of Fordhook bush lima beans. Addition of ½ ppm of boron to .005 per cent alpha-naphthaleneacetic acid or the use of .01 per cent of the calcium salt of alpha-naphthaleneacetic acid as a spray also had no significant effect on total yield.

Alpha-naphthaleneacetic acid dust at a concentration of 50 ppm had no significant effect on yield of fresh marketable pods of 13 varieties of bush lima beans.

A possible explanation for the fact that these wide ranges of concentrations of alpha-naphthaleneacetic acid failed to increase yield of these bush lima beans might be that the temperatures during blooming and setting period of lima beans were unusually favorable for pod setting. With temperature conditions not so favorable for pod setting, there is a possibility that yield of lima beans might be increased or decreased by the use of these growth regulators.

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Susceptibility of Some of the Cucurbits to DDT Injury

By H. D. Brown and E. K. Alban, *Ohio State University, Columbus, O.*

During the summer of 1945, many growers in Ohio reported various degrees of injury to cucurbits following applications of DDT sprays and dusts. For this reason it was decided to grow some of the important varieties and determine the type and extent of damage incurred following the use of DDT. In addition, preliminary reports had indicated that relatively low concentrations of this insecticide very effectively controlled the striped and twelve-spotted cucumber beetles and the squash bug. To test the possibility of employing the insecticide on trap crops as a control for commercial plantings, the cucurbit varieties to be tested were planted between commercial plantings of muskmelons. The commercial muskmelons were dusted with rotenone and a 4 per cent copper dust, while the trap crop, or cucurbit varieties, were sprayed with DDT.

Forty-two cucurbit varieties, including 24 pumpkin and squash, 11 muskmelon, and 7 watermelon varieties were planted. These varieties were selected for the most part because of their adaptability to central Ohio conditions. The watermelon varieties, though not ordinarily grown in this section were included to study their reaction to this spray. Both the commercial and trap crops were planted June first. Ten hills of each variety of the cucurbits were planted under the permanent irrigation lines and the commercial plantings were made in the area between the lines. Replantings were made to assure a good stand. An adequate stand was obtained with all of the varieties included in the test. The plants were thinned to three or four plants per hill.

Three concentrations of DDT were used and in all cases applied as a spray. These sprays consisted of 2, 8, and 16 pounds of 50 per cent DDT (Deenate, Du Pont Chemical Company) per 100 gallons. These various concentrations were progressively increased during the growing season, as indicated in Table I. The spray was applied with a 3-gallon Hudson type sprayer and the foliage was adequately covered with each application. Observations were made within 24 hours after each spray and at intervals between the next application. The first spray, at the rate of 2 pounds of 50 per cent DDT per 100 gallons, was applied when most of the plants were developing true leaves. The varietal names, concentration of DDT, date of application and general plant response are included in Table I.

Discussion of Results

Watermelon:—The damage to all of the watermelon varieties was confined for the most part to slight marginal chlorosis of leaves and some dwarfing. An increase in the concentration in the spray did not increase this damage to any marked degree. The Preserving Citron revealed the greatest tolerance to the DDT sprays. Flower formation and some fruit sets were obtained, but all of the varieties were slightly retarded in their growth. Cold temperatures and subsequent light frosts prevented further development of the fruit. As mentioned previously, watermelons are not normally grown in this area due to the relatively heavy soils and the short frost-free season.

Squash and Pumpkin:—The summer varieties with but one exception were severely damaged by even the lowest concentration of DDT as indicated in Table I. The exception was Dark Green Zucchini which, though slightly damaged (marginal chlorosis of the older leaves), recovered rapidly and a satisfactory harvest was obtained. The damage to most of these varieties began with the first spray and was characterized by the development of chlorotic areas along the leaf margins. This yellowing soon spread throughout the leaf blade and in some cases was evident in the petioles and stem. New growth in many plants was entirely inhibited and flower production held at a minimum. Practically no marketable fruits were harvested from these summer varieties with the exception of the Dark Green Zucchini.

The response of the winter varieties of pumpkin and squash to DDT sprays were variable. Table Queen, for instance, was severely damaged with the lowest concentration. Plants of the Pink Banana and Mammoth Potiron varieties on the other hand exhibited great tolerance to any concentrations of DDT used. Common Yellow Field, Connecticut Field, Golden Delicious, Buttercup, and the Hubbard squashes were damaged with the first few sprays, but recovered rapidly. Subsequent spray applications, though containing a higher concentration of DDT, did not cause any great increase in foliage damage. The older leaves of the plants of the above-mentioned varieties were yellowed and some necrotic areas were present, but this did not seem to interfere greatly with the fruit development.

Muskmelon:—None of the commercially important muskmelon varieties tested exhibited any great tolerance to DDT sprays. A slight dwarfing was evident, although not all varieties were affected the same. Yellowing or marginal chlorosis of the leaves was not nearly as serious with the varieties tested as had been reported during the previous year. Cooler weather and abundant rainfall during June, July, and the first week of August probably influenced the severity of damage as revealed in the 1946 tests. However the muskmelon varieties which received only rotenone and copper dusts were far superior in plant growth and fruit production as compared to those varieties which received the DDT sprays. The Banana muskmelon was injured the least and general plant growth and fruit development were nearly normal.

General:—The flower and fruit development of the cucurbit varieties tested did not indicate any specific damage due directly to the DDT sprays applied. Actual counts of flowers and fruit were not made but it appeared that the determining factor in flower and fruit development was the general plant condition. Where foliage of the plants had been seriously damaged, there were few or no flowers and of course practically no fruit. In Table I, the flower and fruit production are shown to be directly associated with the extent of damage to the plants. Flowers and fruits were examined after each spray and in no case was injury, traced to DDT sprays, apparent. The last spray, con-

TABLE I—General Plant Response of Forty-Two Cucurbit Varieties Following Application of Various Concentrations of DDT Sprays in the 1946 Season at Columbus, Ohio*

Varieties	2 Lbs. DDT (50 Per Cent) Per 100 Gal	8 Lbs. DDT (50 Per cent) Per 100 Gal	Flower and Fruit Development	Fruit Harvested
	Jun 22, 27, and Jul 5	Jul 11, 18, 29 and Aug 12		
Stone Mountain	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Dixie Queen	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Cole's Early	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Tom Watson	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Improved Kleckley's Sweet	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Sweetheart	Dwarfing and some marginal chlorosis	Slight dwarfing and mild chlorosis, fair recovery of new growth	Good	**
Preserving Citron	Dwarfing and some marginal chlorosis	Mild Chlorosis, good recovery	Good	**
Giant Golden Straightneck	Mild chlorosis	Severe general chlorosis, new growth very weak	Fair	Poor
Early Prolific Straightneck	Mild chlorosis	Severe general chlorosis, new growth very weak	Fair	None
Cocozelle	Mild chlorosis	Severe general chlorosis, new growth very weak	Fair	None
Zucchini	Severe general chlorosis	Severe general chlorosis, practically no new growth	None	None
Early White Bush	Dwarfing and marginal chlorosis	Severe general chlorosis, practically no new growth	Fair	Poor
Giant Golden Summer Crookneck	Dwarfing and marginal chlorosis	Severe general chlorosis, practically no new growth	Good	Fair
Mammoth White Bush Scallop	Dwarfing and marginal chlorosis	Severe damage—many plants dead	Poor	Poor
Mammoth Yellow Bush Scallop	Dwarfing and marginal chlorosis	Severe damage—many plants dead	Poor	None
Dark Green Zucchini	Very good growth, some slight marginal chlorosis	Excellent growth, new growth not affected	Excellent	Excellent
Green Striped Cushaw	Very good growth, some slight marginal chlorosis	Moderate general chlorosis, new growth fairly strong	Fair	Fair
Common Yellow Field	Excellent growth, some slight marginal chlorosis	Excellent growth, good recovery, new growth not damaged	Excellent	Excellent
Connecticut Field	Excellent growth, some slight marginal chlorosis	Excellent growth, older leaves slightly damaged	Excellent	Excellent
Mammoth Potiron	Excellent growth, some slight marginal chlorosis	Excellent growth, older leaves slightly damaged	Excellent	Excellent
Winter Luxury	Severe dwarfing and general chlorosis	Severe general chlorosis, practically no growth	Poor	Poor
Large sweet cheese	Dwarfing and some chlorosis	General chlorosis, fair growth	Good	Good
Blue Hubbard	Slight damage older leaves	General chlorosis, new growth fairly good	Good	Good
Green Hubbard	Slight damage older leaves	General chlorosis, new growth fairly good	Good	Good
Pink Banana	Practically no damage	Excellent growth	Excellent	Excellent
Livingston's Pie	Dwarfed and general chlorosis	Severe chlorosis	Fair	Fair
Chicago Warted Hubbard	Slight yellowing of older leaves	Older leaves damaged, new growth excellent	Good	Good
Golden Delicious	Very slight yellowing of older leaves	Older leaves damaged, new growth excellent	Good	Good
Buttercup	General chlorosis	Older leaves damaged, new growth excellent	Good	Good
Acorn (Table Queen)	General wilting of plant, general chlorosis	Severe injury, some plants dead	Poor	None
Golden Hubbard	Very good growth, slight marginal chlorosis	Slight damage to older leaves, new growth excellent	Good	Good

Honey Dew	Severe chlorosis	Severe damage, most plants dead	Poor	None
Rocky Ford	No chlorosis, growth fair	Severe damage, most plants dead	Fair	Poor
Hearts of Gold	No chlorosis, growth fair	Severe damage. most plants dead	Fair	Poor
Livingston's Tip Top	No chlorosis, growth good	Very good growth	Good	Good
Delicious	No chlorosis, growth good	Very good growth	Good	Good
Pride of Wisconsin	No chlorosis, growth fair	Growth fair, some chlorosis	Good	Fair
Queen of Colorado	No chlorosis, growth fair	Growth fair, some chlorosis	Good	Fair
Bender's surprise	No chlorosis, growth fair	Very good growth	Good	Good
Hales Best	No chlorosis, growth fair	Growth fair, some chlorosis	Fair	Poor
Banana	No chlorosis, excellent growth	Excellent growth	Excellent	Excellent
Hales Best No. 36	No chlorosis, growth fair	Growth fair	Fair	Fair

*A spray containing 16 pounds DDT (50 per cent) was applied on September 20 and did not increase damage to existing plants.

**Frost damage before fruits reached maturity; cool weather retarded plant growth and fruit development.

taining 16 pounds of DDT per 100 gallons, did not cause any damage to the fruits in the field at the time.

No check on insect control other than observation was obtained with the commercial or the trap crops. However, it was difficult to find striped or twelve-spotted cucumber beetles, or squash bugs on either commercial or trap crop throughout the growing season. Another melon planting, located about 600 feet from these plots, and dusted only with rotenone had a rather heavy infestation of the striped and twelve-spotted cucumber beetles. Many dead beetles were found at the end of the season under the foliage of trap crops but no live beetles or squash bugs.

SUMMARY

Forty-two varieties of cucurbits, including 24 squash and pumpkin, 11 muskmelon and 7 watermelon varieties were grown in the field and sprayed with various concentrations of DDT sprays. All of the varieties under test exhibited at least some damage to foliage following application of DDT sprays. Common Yellow Field, Connecticut Field, Mammoth Potiron, Pink Banana, Buttercup, Golden Delicious, Blue Hubbard, Chicago Warted Hubbard, Golden Hubbard, Dark Green Zucchini, and Banana Melon were the only cucurbit varieties in this test which recovered sufficiently to produce a satisfactory crop. It is possible that these varieties might be used as trap crops and sprayed with DDT along with other commercial cucurbits treated only with rotenone.

The striped and twelve-spotted cucumber beetles and the squash bug were adequately controlled in all plantings.

The Value of Certain Aromatic Naphthas and Growth Regulators as Soil Treatments for Weed Control in Vegetables[1]

By JOHN R. HAVIS and ROBERT D. SWEET, *Cornell University, Ithaca, N. Y.*

THE fact that weeds are easier to kill in early stages of growth is generally recognized, and the application of that fact may be of high practical value with respect to the use of chemicals in controlling weeds in vegetables for which no selective herbicide has been found.

In preliminary tests in the early spring of 1946 it was found that when certain growth regulating compounds, including 2,4–dichlorophenoxyacetic acid and methyl ester of alpha naphthalene acetic acid were applied to the soil at 4 and 12 pounds per acre, the growth of weeds was definitely inhibited. Later that year a more comprehensive experiment was set up to further test the value of these chemicals and of some aromatic naphthas for weed control and to determine the interrelationships between time of application, weed control and crop injury.

METHODS

The experiment was conducted on Dunkirk fine sandy loam at Ithaca, New York. The weed population consisted of purslane *(Portulaca oleracea)*, moderate amounts of pig weed *(Amaranthus retroflexus)*, galinsoga *(Galinsoga ciliata)*, crab grass *(Digitaria saguinalis)*, and a few additional weeds and summer grasses.

Prior to disking, the area was supporting a heavy crop of purslane and a moderate growth of the other weeds mentioned above. When the soil was disked and harrowed 4 days prior to the first application, living sprigs of purslane were left at the soil surface.

Two types of materials were used in this experiment-growth regulators and aromatic naphthas.[2]

The growth regulators were:

1. 2,4–dichlorophenoxyacetic acid in the form of a 75 per cent soluble ammonium salt.
2. Methyl ester of alpha naphthalene acetic acid with 10 per cent "Tween 80" as wetting agent.
3. Thiourea in the form of soluble salt.

The aromatic naphthas were:

1. H. S. Solvent — approximately 15 per cent aromatic hydrocarbons, boiling range 317 to 429 degrees F, representing a low aromatic naphtha with low boiling range. It closely approximated Stoddard Solvent.

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[1] Paper No. 285, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

The authors are indebted to Standard Oil Development Company for a special grant which made much of this work possible.

[2] The authors are indebted to the following for supplying chemicals used in this experiment: American Cyanamide and Chemical Corporation, Dow Chemical Company, Gulf Oil Company, Standard Agricultural Chemicals, Inc., and Standard Oil Company of New Jersey.

2. Mentor 25 — 90 per cent aromatic hydrocarbons, boiling range 420 to 515 degrees F, representing a naphtha having a high aromatic content and high boiling range.
3. Solvesso 3 — 89 per cent aromatic hydrocarbons, boiling range 345 to 410 degrees F, representing a naphtha with high aromatics and low boiling range.

Each chemical was applied on an area 20 by 20 feet, with two replications. The rates of application were 7.5 pounds per acre of pure chemical for growth regulators and 150 gallons per acre for aromatic naphthas. All applications were made by spraying the soil surface using knapsack hand operated sprayers.

All materials were applied on July 19, 1946, as preplanting treatments. On July 25, 6 days following the preplanting treatments, one-half of each 20 by 20 foot area was planted to Tendergreen beans, and Golden Cross sweet corn in rows 15 inches apart. A small hand seeder was used for both crops. Three days later, one-half of the planted area was given a pre-emergence treatment. The unplanted half of the 20 by 20 foot area was planted to beans and corn on August 4. Pre-emergence treatments were applied August 6 in the same manner as in the earlier planting.

On August 20, weed counts, and stand and height measurements of beans and corn were taken on all plots.

The weed control was evaluated by counting the number of weeds enclosed by a wire frame 1 foot square in three systematically chosen locations within each plot. The average number of weeds per square foot was used as the basis for comparisons.

The stand of corn was so severely damaged by birds that these data are not included. For a measure of stand of beans, a count was made of the two center rows for a distance of 2 yards, except when it was clearly evident that the crop had been damaged by birds. In those few cases the adjoining rows were chosen. Counts began at least 1 foot from the plot border.

For height measurements, six or more plants selected at random were measured and an average taken. Corn was measured to the throat, beans to the growing point.

All data were analyzed by analysis of variance.[3]

SOIL AND WEATHER CONDITIONS AT TIMES OF APPLICATION

At the pre-planting treatment the soil surface was dry. Numerous sprigs of purslane were alive and taking root in the soil, but there were no weed seedlings visible above ground. The temperature was about 90 degrees F, moderate wind, and rather low humidity.

At the first pre-emergence treatment the soil surface was dry. There was a considerable number of weed seedlings, especially in the H. S. Solvent and Solvesso 3 plots. The temperature was about 70 to 75 degrees F, very little wind, but rather low humidity.

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[3] The author wishes to acknowledge the assistance of Dr. W. C. Jacob in the statistical treatment of the data.

At the second pre-emergence treatment the soil surface was moist. The temperature was about 65 to 70 degrees F, practically no wind, and very high air humidity.

RESULTS

The results are presented in two principal sections; first, the effects of the chemicals on weeds, and second, their effects on stand and height of crops.

Effect of Chemicals on Weeds:—When a particular chemical controlled broad-leaved weeds, it also controlled grasses. For this reason the results on weed control are given on the basis of total weed counts, including grasses, rather than for the separate groups.

The effects of the chemicals on number of weeds per square foot are shown in Table I.

TABLE I—MEAN VALUES* FOR NUMBER OF WEEDS PER SQUARE FOOT FROM THE VARIOUS TREATMENTS

Chemical	First Planting		Second Planting	
	Pre-Planting Treatment	Pre-Emergence Treatment	Pre-Planting Treatment	Pre-Emergence Treatment
2,4-Dichlorophenoxyacetic acid	3.23	3.61	3.72	1.85
ME of a naphthalene acetic acid	3.98	1.87	3.38	1.63
Thiourea	9.77	7.32	6.92	6.80
H S Solvent	11.58	6.57	12.70	2.68
Mentor 25	8.02	8.89	5.54	1.22
Solvesso 3	11.42	6.82	11.82	1.54
Control	10.98	10.98	10.20	10.20

Least difference for significance at .01 level, 6.46.

*Number of weeds per square-foot area transformed into $x' = \sqrt{x+.5}$.

The data in Table I show that 2,4–dichlorophenoxyacetic acid applications eliminated practically all weeds. There was no significant difference in number of weeds per square foot between plots receiving pre-planting treatment and those receiving the additional pre-emergence treatment, nor were there differences between plots receiving the pre-emergence treatment 9 days after the pre-planting treatment and those treated 18 days after the original treatment.

The action of methyl ester of alpha naphthalene acetic acid in reducing numbers of weeds was similar to that of 2,4–D.

No significant reduction in weeds resulted from applications of Thiourea.

The pre-planting application of H. S. Solvent did not affect the weed population, probably due to the fact that no seedlings were above ground. A considerable reduction in weeds following pre-emergence application in the first planting is evident from Table I. Much greater reduction in weeds occurred following the second pre-emergence treatment. At the first pre-emergence treatment, many, but not all weed seeds had germinated, and the seedlings were killed by the solvent. In the later treatment practically all of the weed seed capable of germination that season had done so, and in addition, atmospheric conditions were unfavorable for rapid evaporation. It is believed that these two factors contributed to the excellent control of weeds in the pre-emergence treatment given the second planting.

In the second planting, there was a highly significant reduction in weeds in the plots receiving the pre-emergence treatment of Mentor 25. It is thought that the same conditions influencing the effectiveness of H. S. Solvent were operating in the case of Mentor 25.

No control of weeds resulted from application of Solesso 3 when used as a pre-planting treatment. This material evaporated very rapidly from the soil and no seedlings were above ground at the time of application. In the second planting the pre-emergence treatment resulted in a highly significant reduction of weeds. As shown in Table I. Solvesso 3 applied under conditions of low evaporation and when practically all weeds were above ground, gave control comparable to that obtained with 2,4–D, M.E. alpha naphthalene acetic acid, and Mentor 25.

TABLE II—STAND OF BEANS (NUMBER OF PLANTS IN 2 YARDS OF ROW)

Chemical	First Planting		Second Planting	
	Pre-Planting Treatment	Pre-Emergence Treatment	Pre-Planting Treatment	Pre-Emergence Treatment
2,4-dichlorophenoxyacetic acid	8.2	3.5	10.0	3.8
ME of a naphthalene acetic acid	10.5	4.2	17.2	10.0
Thiourea	14.2	12.5	12.0	15.2
H S Solvent	14.2	14.5	11.5	5.8
Mentor 25	13.2	16.0	13.8	8.8
Solvesso 3	16.2	12.8	10.8	4.5
Control	14.0	14.0	13.2	13.2

Least difference for significance at .01 level, 6.6
Least difference for significance at .05 level, 4.8.

Effect of Chemicals on Crops:—The effects of the chemicals on stand of beans are presented in Table II. As mentioned earlier, the effects of the chemicals on stand of corn is omitted because of excessive damage by birds. The effects on height of both crops are presented in Tables III and IV.

TABLE III—AVERAGE HEIGHTS OF SWEET CORN (INCHES)*

Chemical	First Planting		Second Planting	
	Pre-Planting Treatment	Pre-Emergence Treatment	Pre-Planting Treatment	Pre-Emergence Treatment
2,4-dichlorophenoxyacetic acid	4.00	1.75	2.75	2.00
ME of a naphthalene acetic acid	6.25	3.50	3.50	2.75
Thiourea	7.50	7.75	4.00	4.00
H S Solvent	5.50	7.25	3.25	3.00
Mentor 25	7.50	7.25	4.00	3.25
Solvesso 3	7.25	7.00	3.25	3.00
Control	7.50	7.50	3.25	3.25

Least difference for significance at .01 level, 2.82 for first planting; 0.88 for second planting.
Least difference for significance at .05 level, 2.00 for first planting; 0.63 for second planting.
*Measurements were made August 20.

No hand weeding was done on control plots or plots where chemicals were ineffective. Therefore, in comparing heights of beans the inhibiting influence of weeds on growth of the crop must be considered.

Since height measurements were made on both plantings on August 20, no direct comparisons between the first and second planting dates are possible.

TABLE IV—AVERAGE HEIGHTS OF BEANS (INCHES)*

Chemical	First Planting		Second Planting	
	Pre-Planting Treatment	Pre-Emergence Treatment	Pre-Planting Treatment	Pre-Emergence Treatment
2,4-dichlorophenoxyacetic acid	4.25	2.75	3.25	2.25
ME of a naphthalene acetic acid	5.25	2.50	3.75	2.75
Thiourea	10.00	7.75	4.75	4.00
H S Solvent	7.50	11.50	4.00	3.00
Mentor 25	11.25	11.75	4.00	3.75
Solvesso 3	9.50	8.00	4.00	3.25
Control	11.00	11.00	4.25	4.25

Least difference for significance at .01 level, 3.36 for first planting; 1.04 for second planting.
Least difference for significance at .05 level, 2.38 for first planting; 0.74 for second planting.
*Measurements were made August 20.

The pre-planting treatment with 2,4–D gave a significant reduction in stand of beans in the first planting, but not in the second planting (Table II). As would be expected, the pre-emergence treatments markedly reduced the stand of beans of both the first and second planting.

As is evident from Tables III and IV, 2,4–D seriously stunted the growth of both beans and corn in all cases except the second planting of corn receiving the pre-planting treatment. Again, the most serious effects of 2,4–D were following the pre-emergence treatments. The relative difference between the 2,4–D plots and the control increased as the season progressed.

A third planting of beans was made August 22 in 2,4–D plots to determine the persistence of injurious amounts of the chemical. The beans germinated and grew normally in all plots, even those which had been treated only 16 days previously. A possible explanation for this lack of toxicity is offered in the discussion section.

As can be seen in Table II, Methyl ester of alpha naphthalene acetic acid applied as pre-planting treatment gave no significant reduction in stand of beans at either planting date, but the pre-emergence treatment on the first planting resulted in marked reduction in stand. In the second planting however, there was no significant reduction in stand as compared to control plots.

From Table III it can be seen that when methyl ester of alpha naphthalene acetic acid was applied as pre-planting treatments, the height of corn in neither planting was significantly less than in the control plots. Serious stunting of beans however, resulted from this treatment in the first planting, but not in the second planting. This difference in the toxicity of the pre-emergence treatment between the first and second plantings may have been the result of weather conditions, the volatile character of the material, or a combination of the two.

There was no effect from Thiourea on stand of beans. It did not affect height of corn under any conditions. Significantly less height of beans occurred only in the first planting, pre-emergence treatment.

The only significant reduction in stand of beans from H. S. Solvent (see Table II) was in the plots receiving pre-emergence treatment, second planting. Probably this damage was due to the low evaporation rate at the time of application.

Height of the first planting crops receiving the pre-planting treatments of H. S. Solvent was less than those in control plots. It is likely, however, that this was a result of the large weed population in those plots (see Table I) and not due to any toxicity of the chemical. Although there was a marked reduction in stand in the pre-emergence plot, second planting, there was only a slight effect on height. This indicates that the toxic effect of the chemical was only temporary.

When Mentor 25 was used, the only plot having significant reduction in stand of beans was that receiving the pre-emergence treatment at the second planting. As with H. S. Solvent, this was probably due to the low evaporation rate at the time of application. There was no effect of Mentor 25 on height of corn or beans.

The effect of Solvesso 3 on the stand of beans was the same as with that of Mentor 25. No treatment affected the height of corn, but the height of beans was somewhat less in pre-emergence treatments than in control plots.

TABLE V—PRECIPITATION AND TEMPERATURE DURING CERTAIN PERIODS IN THE EXPERIMENT*

Treatment	Days	Total Precipitation (Ins)	Mean Temperature
Pre-planting treatment to first planting .	6	1.19	70.67
Pre-planting treatment to second planting	16	1.98	67.81
Pre-planting treatment to third planting.	34	6.00	66.74
Second pre-emergence to third planting. . .	16	2.62	65.50

*From monthly meteorological summary prepared by the Agronomy Department, Cornell University.

DISCUSSION AND SUMMARY

The third planting of beans superimposed on the 2,4–D plots germinated and grew normally. This is in sharp contrast to the second planting. In both instances 16 days had elapsed between the most recent application of 2,4–D and time of planting.

Mitchell and Marth (1) have pointed out the importance of moisture for dissipation of 2,4–D from soil. It is evident from Table V that the principal difference in conditions between the 16-day periods is the precipitation. During the period between pre-planting treatment and the second planting, the greatest amount of rainfall in one day was 0.85 inches, whereas 1.13 inches fell in one day during the period between the second pre-emergence treatment and the third planting. Since the 2,4–D was in the form of a soluble salt, the amount of daily rainfall may be important in leaching of the material. The importance of leaching in this respect has been suggested by De Rose (2). It is also possible that the moist soil conditions which prevailed prior to the third planting may have been favorable for micro-organism action in breaking down 2,4–D.

2,4–D and methyl ester of alpha naphthalene acetic acid were very effective in controlling weeds when applied to the soil at the rate of 7.5 pounds per acre before weeds had appeared above ground.

Methyl ester of alpha naphthalene acetic acid was just as effective as 2,4–dichlorophenoxyacetic acid for weed control, but must less injurious to crops. Crop injury would probably be reduced by use of smaller quantities of these growth regulators.

Thiourea was ineffective in controlling weeds and in general was not toxic to corn or beans.

Three different aromatic naphthas were applied to the soil at 150 gallons per acre. The time of application and weather conditions influenced the toxicity of the naphthas to weeds and to crops. Unsatisfactory weed control was obtained when they were applied to the soil before weeds had emerged. Post-emergence treatments gave excellent weed control. It is therefore questionable if naphthas are effective except when used as contact herbicides.

Injury to crops resulted only when the naphthas were applied as pre-emergence sprays under conditions unfavorable for rapid evaporation. Their volatility make the naphthas particularly suitable for pre-emergence treatments, when rapid loss of toxicity is desired.

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The Use of Chemicals for the Control of Weeds in Carrots[1]

By R. E. NYLUND, *University of Minnesota, St. Paul, Minn.*

THE cost of hand weeding of row crops such as carrots constitutes a considerable portion of the total cost of production of such crops. Certain oils have given good control of weeds in carrots and other members of the Umbelliferae family. Stove oil has been used successfully for this purpose for a number of years in California (3, 8). More recently Lachman (6) has found a napthenic oil, Sovasol No. 5 (Stoddard Solvent), to be effective under Massachusett's conditions. His results have been confirmed by other workers (4, 11, 12). Other oils have been used with varying results. Kerosene has been found by some workers (1, 2, 10) to be satisfactory for weed control in carrots while others (5, 8, 12) have reported poor results with it. Stove oil has given satisfactory results (8, 10) while various other fuel oils have been found to be either toxic to the crop or have given poor weed control (1, 4, 5, 10, 12). Lachman (7) has tested a number of petroleum oils which pass the specifications of Stoddard solvent and obtained good weed control with them. It is apparent from the above reports that petroleum oils, having the same name but from different sources, differ in their toxicity to weeds and carrots. Sweet, *et al* (10) tested kerosenes from different sources and found them to vary in toxicity.

The nature of toxicity of petroleum oils to plants has been studied by a number of workers (3, 9, 13) and discussed by others (7, 10) and need not be repated here. According to Robbins, *et al.* (9) the toxicity of various petroleum oils is due to the sulphonatable compounds (aromatics and olefins) present in such oils. Since specifications of various distillate fractions are not exact, oils from different sources and sold under the same name may vary widely in both physical and chemical properties and thus vary in toxicity to plant tissue. Crafts and Reiber (3) suggest that oils containing an unsulphonatable residue of not in excess of 75 per cent (25 per cent aromatic compounds) be used as weedicides. Lachman (7) states that apparently an aromatic content of about 15 per cent is necessary to insure good weed control.

The experiments reported here were conducted to determine: (a) the effectiveness of various petroleum oils containing known amounts of aromatic compounds and of other chemicals as selective herbicides for carrots, and (b) to determine the number of times such weedicides

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[1] Paper No. 2324 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

The writer wishes to thank Dr. Earl Wookey of the W. H. Barber Oil Company of Minneapolis, Minnesota, for furnishing the deodorized kerosene, regular kerosene, range oil, Diesel fuel, No. 2 gas oil, and solvent "F" used in this study, and also for determining the percentages of aromatic compounds present in the oils used. The writer also wishes to acknowledge his indebtedness to the late Dr. R. B. Harvey of the Division of Agricultural Botany for providing the Weedone, Sinox, heater oil and various 2,4-dichlorophenoxyacetic acid solutions used in this study.

can be applied without affecting adversely yield and flavor of carrots. Two experiments were conducted during the summer of 1945 and one during the summer of 1946.

MATERIALS AND METHODS

Experiment I:—This experiment was carried on at University Farm on an upland soil. Chantenay carrots were seeded on April 26, 1945 and the field was divided into 16 two-row plots 15 feet in length in each of four blocks. The 15 chemicals listed in Table I were applied to randomized plots in each block on June 8, at which time the carrots had 3 to 4 true leaves. On June 25, a second application was made to one row of each of the two-row plots. The oils used were applied in the evening when the air temperature was 65 to 70 degrees F, while the other chemicals were applied at mid-day when the air temperature was 80 to 90 degrees F. Weed counts were taken on the once-sprayed rows on June 18, 10 days after spraying, and in the twice-sprayed rows on July 1, 6 days after the second spraying. Immediately after the weeds had been counted all plots were hand weeded and were kept free of weeds by hand weeding to the time of harvest. The stand and yield of carrots were recorded at harvest.

Experiment II:—At the Fruit Breeding Farm on muck soil, Nantes carrots were seeded on June 12, 1945. Nine single-row plots were laid out in each of five blocks. The eight materials listed in Table II were applied to randomized plots in each block on July 13, at which time the carrots had 3 to 4 leaves. Weeds were counted 4 days later. Due to the fact that the land had been prepared several days before the carrots were seeded the weeds were quite large (4 to 12 inches tall) at the time of the first application of weedicides. For that reason, weed control was not as satisfactory as at University Farm. Thus, on July 17, 4 days after the first applications, weedicides were applied for a second time on some of the plots. Eight days later weeds were counted on the twice-sprayed plots and all plots were hand weeded. All plots were harvested on September 24 at which time the number and weight of carrots in each plot were recorded.

In both experiments a brass-tanked knapsack sprayer having an ordinary sprayer nozzle was used for applying the weedicides. All materials were applied at the rate of approximately 100 gallons per acre.

Experiment III:—The 1946 experiment was conducted on a muck soil at the Fruit Breeding Farm. Nantes carrots were seeded on May 1 and 13 single-row plots 15 feet in length were laid out in each of six blocks. Kerosene from one source and Stoddard solvent from four sources were the only weedicides used. The kerosene and Stoddard solvent B were applied to plots one, two, and three times, while the Stoddard solvents from other sources (P, D, and W) were applied only once. One series of plots sprayed with Stoddard solvent B one, two, and three times were left unweeded throughout the season. All other plots were hand-weeded 3 to 4 days after spraying. Sprays were applied at the rate of 80 gallons per acre on June 4, June 25, and July 12 using a knapsack sprayer fitted with a Monarch No. 059 flat-fan nozzle. Stands and yields were recorded at time of harvest which was August 3 for the first three blocks and August 16 for the second three blocks. Samples were taken at each date of harvest for judging of flavor.

RESULTS

Results on Upland Soil (Experiment I):—The percentages of the various weed species present in the field at University Farm at the time of spraying were as follows: Yellow Foxtail *(Setaria glauca,* L.) 54 per cent, Lambsquarters *(Chenopodium album,* L.) 28 per cent, Purslane Speedwell *(Veronica peregrina,* L.) 8 per cent, Lady's Sorrel *(Oxalis corniculata,* L.) 7 per cent, and Red-root Pigweed *(Amaranthus retroflexus,* L) 3 per cent. None of the weed species present were more resistant than others to materials which were effective weedicides.

Table I gives the stands of weeds and carrots and yields of carrots at University Farm after application of the indicated treatments. Weedone, Sinox, and 2,4–D in various solvents were ineffective as weedicides as they failed to kill grasses and greatly reduced the stands and yields of carrots. Sulphuric acid, while it did not reduce yields, was only partially effective in killing weeds.

Of greatest interest are the effects of the various petroleum oils (Treatment 2 to 8, Table 1). All of the oils used significantly reduced

TABLE I—STANDS OF WEEDS, STANDS OF CARROTS, AND YIELDS OF CARROTS AFTER ONE AND TWO APPLICATIONS OF VARIOUS WEED-KILLING SUBSTANCES AT UNIVERSITY FARM (1945)

Treatment	Per Cent Aromatic Compounds	Stands of Weeds and Carrots and Yield of Carrots After Indicated Number of Applications					
		Total Weeds		Stand Carrots Per 15 Feet Row		Yield Carrots Per Acre	
		Number 1	Number 2	Number 1	Number 2	Bushels 1	Bushels 2
1 Unsprayed	—	34	26	72*	72	626*	626
2 Odorless kerosene	5	6	9	60	76	604	576
3 Regular kerosene	16	5	2	74	77	728	566
4 Range oil	19	5	10	65	61	590	508
5 Heater oil	20	4	6	72	56	629	466
6 Diesel fuel	32	4	1	54	62	524	485
7 No. 2 Gas oil	36	0	0	40	26	444	266
8 Solvent "F"	70	1	0	45	9	463	109
9 2½ per cent sulfuric acid	—	28	16	77	28	620	290
Difference necessary for odds of 19:1				24	24	245	245
*Difference necessary for odds of 19:1 between application means				13		133	
10 Weedone 1–60	—	22	28	20	0	166	0
11 Sinox 1–80	—	26	22	22	6	246	67
12 2,4-D in Carbowax	—	18	13	1	1	17	2
13 2,4-D in Ammonium carbonate**	—	24	27	2	0	9	0
14 2,4-D in Levulinic acid**	—	16	5	1	1	5	3
15 2,4-D in Sodium carbonate**	—	18	21	3	0	15	0
16 2,4-D in Triethylamine**	—	20	23	1	0	6	0
Difference necessary for odds of 19:1		18	18	—	—	—	—

**Used at 875 parts per million.

stands of weeds present. In general, the higher the aromatic-compound content of the oil, the greater was its effectiveness in killing weeds. However, oils containing more than 20 per cent aromatic compounds (Diesel fuel, No. 2 gas oil, and Solvent F) reduced stands and yields of carrots. Oils containing 5 to 20 per cent aromatic compounds (odorless kerosene, regular kerosene, range oil, and heater oil) were most effective in reducing stands of weeds without reducing stands and yields of carrots. All of the oils when applied twice tended to reduce yields of carrots. Unfortunately, the numbers of weeds occurring in the field at University Farm were rather low so that the effectiveness of the oils as weed killers is not too apparent.

Results on Muck Soil, 1945 (Experiment II):—On the muck soil on which this experiment was conducted a slightly greater variety of weed species were present and weeds occurred in considerably greater numbers than at University Farm. The weed species present were: Crabgrass *(Digitaria sanguinalis* (L.) Scop.) 38 per cent, Barnyard Grass *(Echinochloa crusgalli* (L.) Beaux.) 3 per cent, Red-root Pigweed *(Amaranthus retroflexus,* L.) 38 per cent, *Elisia nyctelea,* L. 8 per cent, Lady's Sorrel *(Oxalis corniculata,* L.) 5 per cent, Curled Dock *(Rumex crispus,* L.) 4 per cent, Lady's-tongue Smartweed *(Polygonum persicaria,* L.) 2 per cent, Lambsquarters *(Chenopodium album,* L.) 1 per cent, Common Purslane *(Portulaca oleracea,* L.) 1 per cent. Table II shows the stands of weeds, stands of carrots, and yields of carrots after one or two applications of various oils. Odorless kerosene, No. 2 gas oil, and solvent "F" were applied only once; the other oils tested were applied twice. Odorless kerosene, while it did reduce the stands of weeds to some extent was not as effective as oils having a higher aromatic-compound content. Oils having an aromatic-compound content of 32 per cent or higher (Treatments 7 through 9) were most toxic to weeds but also seriously reduced stands and yields of carrots. Oils in the range of 16 to 24 per cent aromatic compounds were most satisfactory as they reduced the stands of weeds without seriously reducing stands and yields of carrots. Regular kerosene

TABLE II—STANDS OF WEEDS, STANDS OF CARROTS, AND YIELDS OF CARROTS AFTER ONE OR TWO APPLICATIONS OF VARIOUS OILS AT UNIVERSITY FRUIT BREEDING FARM (1945)

Treatment	Per Cent Aromatic Compounds	Number of Applications**	Total Weeds Per 5 Feet Row (No.)	Stand of Carrots Per 15 Feet Row (No.)	Yields of Carrots Per Acre (Bu)
1 Unsprayed	—	—	107	62	251
2 Odorless kerosene	5	1	69	69	263
3 Regular kerosene	16	2	20	75	280
4 Range oil	19	2	30	54	182
5 Heater oil	20	2	29	64	221
6 50 per cent Kerosene and 50 per cent Diesel fuel	(24)*	2	25	61	190
7 Diesel fuel	32	2	6	30	64
8 No. 2 Gas oil	36	1	4	1	2
9 Solvent "F"	70	1	5	12	31
Difference necessary for odds of 19:1			21	18	52

*Calculated.

**First appication on July 13, second on July 17.

which contained 16 per cent aromatic compounds gave best control of weeds with no apparent reduction in stands and yields of carrots.

All of the species of weeds present in the field, with the exception of Curled Dock, were killed by the oils containing more than 16 per cent aromatic compounds provided the weeds were not over 6 inches tall when the oils were applied.

Results on Muck Soil, 1946 (Experiment III):—In the 1946 experiment on muck soil, the species and percentages of weeds were approximately the same as given above for Experiment II. Table III shows the stands of weeds and carrots and yields of carrots for the indicated treatments. Since few, if any, new weeds appeared in the plots after the second spraying, no weed counts were made after the third application of the weedicides. For some unknown reason, kerosene which had given good control of weeds in 1945 did not reduce stand of weeds in this experiment. This kerosene was obtained from the same oil company as that used in 1945 and contained approximately the same percentage of aromatic compounds as did the 1945 lot (17 per cent versus 16 per cent for the 1945 lot). Stoddard solvent on the other hand, when applied once killed about 70 per cent of the weeds present without materially reducing stands and yields of carrots. A second application of Stoddard solvent further reduced the number of remaining weeds (or newly-emerged) weeds as indicated by Treatment 3 which was unweeded between applications of weedicide. However, two and three applications of either Stoddard solvent or kerosene caused significant reductions in yields of carrots as compared to the yields of unsprayed plots. There were no apparent differences in toxicity of the Stoddard solvents obtained from four different sources.

TABLE III—STANDS OF WEEDS AFTER ONE AND TWO APPLICATIONS, AND STANDS AND YIELDS OF CARROTS AFTER ONE, TWO, AND THREE APPLICATIONS OF VARIOUS WEEDICIDES IN 1946**

Treatment*	Stands of Weeds and Carrots and Yields of Carrots After Indicated Number of Applications							
	Total Weeds Per 5 Feet Row (No.)		Stand Carrots Per 15 Feet Row (No.)			Yield Carrots Per Acre (Bu)		
	1	2	1	2	3	1	2	3
1 Unsprayed . . .	57.7	7.0	166	166	166	582	582	582
2 Kerosene . . .	66.0	2.5	145	133	134	496	384	411
3 Stoddard solvent BU	13.7	0.2	135	129	155	488	444	464
4 Stoddard solvent B	16.5	0	137	129	144	538	401	482
5 Stoddard solvent P .	19 2	—	141	—	—	528	—	—
6 Stoddard solvent D	13 0	—	150	—	—	527	—	—
7 Stoddard solvent W	24.3	—	162	—	—	538	—	—
Difference necessary for odds of 19:1 . . .	17.0	—	n.s	n s	n.s.	95	95	95

*All plots were hand -weeded 3 days after the first and three days after the second spraying with the exception of the Stoddard Solvent BU plots which were never hand-weeded.

**Carrots seeded May 1. Spray, applied on· (1) June 4, (2) June 25, (3) July 12.

Data given in Table IV indicates the length of time objectionable flavors persist in carrots which have been sprayed one or more times with kerosene or Stoddard solvent. It is apparent from Table IV that off-flavors are detectable in carrots at least 39 days after the last application of either kerosene or Stoddard solvent. Lachman (*7*) states that approximately 14 days were required to dissipate the flavor from well-grown roots that had been sprayed once with Sovasol No. 5 (Stoddard solvent). The above results indicate that 39 days after spraying, off-flavors were detectable in carrots which had been sprayed twice with either kerosene or Stoddard solvent while no off-flavors were apparent 52 days after spraying. However, the persistence for that length of time of an oily flavor in sprayed carrots is probably not an important factor since the data given in Table III indicates that two or more applications of Stoddard solvent are probably undesirable due to their detrimental effect on yields. Thus, if carrots were sprayed only once and at the time when carrots have 1 to 3 true leaves, any off-flavors would be dissipated by the time such carrots had reached the harvesting size.

TABLE IV—Persistence of Off-Flavor in Carrots after Spraying with Kerosene or Stoddard Solvent in 1946

Treatment	Date of Spraying	Harvested Aug 3		Harvested Aug 16	
		No. Days After Last Spraying	Foreign Flavors	No. Days After Last Spraying	Foreign Flavors
Unsprayed......	————	—	None	—	None
Kerosene.... ..	Jun 4	60	None	73	None
Kerosene ..	Jun 4 and Jun 25	39	Slight*	52	None
Kerosene . .	Jun 4, Jun 25 and Jul 12	22	Objectionable	35	Slight*
Stoddard solvent	Jun 4	60	None	73	None
Stoddard solvent	Jun 4 and Jun 25	39	Slight*	52	None
Stoddard solvent	Jun 4, Jun 25, and Jul 12	22	Objectionable	35	Slight*

*Probably not objectionable.

Conclusions and Summary

Several chemicals were tested to determine their effectiveness as selective weedicides for carrots and to determine their effects on yields and flavor. Of the materials tested, Stoddard solvent applied once at the rate of 80 gallons per acre gave best control of weeds without reduction in yields. Kerosene gave good control of weeds in two experiments, but gave poor control in a third. Petroleum oils in the range of 16 to 24 per cent aromatic compounds gave good control of weeds without injury to the crop. Oils containing less than 16 per cent aromatics did not give good weed control. Oils containing more than 24 per cent aromatics were most toxic to weeds, but also seriously reduced stands and yields of carrots.

Weedone, Sinox, and 2,4–D in various secondary solvents, were found to be unsuitable for weed control in carrots due to their failure to control weeds and to their toxicity to carrots. Sulphuric acid (2½ per cent, while not toxic to carrots when applied at the 2 to 4 leaf stage, did not give adequate weed control.

All of the materials tested, including Stoddard solvent, when applied more than once reduced yields of carrots. Off-flavors of carrots due to the application of Stoddard solvent or kerosene were perceptible as long as 39 days after spraying, but were not detected in carrots harvested 52 days after spraying.

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Pre-Emergence Spraying for Weed Control in Vegetables[1]

By WILLIAM H. LACHMAN, *Massachusetts State College, Amherst, Mass.*

THE importance and value of the spring tooth weeder and the rotary hoe as tillage implements for combatting weeds in vegetable crops has long been appreciated. This has been especially true in the culture of such crops as corn, beans and potatoes. More often than not these machines have been used after the vegetable seed was planted but before the plumules emerged from the soil. Some farmers have called the process "blind tillage". This cultivation in many cases accomplishes most by harrowing across the rows and controls one crop of weeds at little expense provided the conditions are optimum for killing the disturbed weeds.

Weed burners have also been employed to kill weeds in vegetable crops. The burners kill young weeds by searing them before the crop plumules emerge from the soil. The amount of heat from the burner that penetrates through the soil is very small so that the crop is not ordinarily injured by pre-emergence burning. "For this purpose a battery of ordinary weed burners is mounted on a two-wheel cart in such a way that it burns a strip eight to ten feet wide across the field. Such a machine can kill all the seedlings in 30 acres in a day" (3).

Recently certain chemical sprays have been used in a limited way as pre-emergence weed killers in a number of vegetable crops (1, 2, 3, 4, 7). The purpose of this paper is to assemble the available information on pre-emergence spraying as well as to report the results of a number of experiments by the author in this field.

MATERIALS AND METHODS

Weed seeds frequently germinate and start growing before the planted crop. If the vegetable grower delays planting for a few days after preparing the soil, an even larger proportion of the weeds will start growing. The purpose in pre-emergence control is to kill these small weeds just before the planted crop comes up, thus reducing the amount of hand weeding required. It is necessary therefore to apply a weed killer on the planted fields several days before the plumules of the vegetable crops emerge.

The most widely used chemicals for this purpose have been oils (Diesel or fuel oil and western stove oil) or materials with an oil base. Generally a very low volume of oil is applied since it has been found that an application of 60 to 80 gallons per acre is sufficient where proper equipment (4, 6) is used. Blackman (2) in England has used a 13 per cent solution of sulphuric acid at the rate of 125 to 150 gallons per acre as a pre-emergence spray with good results in fields of parsnips, onions, leeks, carrots, mangolds, and beetroot. Special acid resistant sprayers are necessary, however, to prevent their corrosion even where 2 or 3 per cent sulphuric acid is used.

Other sprays used for pre-emergence weed control include Sinox

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[1] Contribution No. 614 of the Massachusetts Agricultural Experiment Station.

(Sodium dinitro-ortho-cresylate), and Dowspray 66 Improved (Dinitro-sec, butylphenol in oil). Sinox is a selective spray, however, and will not control grasses.

Preliminary investigations indicate that 2,4–D may be of considerable value as a pre-emergence herbicide with beans, sweet corn and spinach (9, 10). Where 2,4–D is used in this manner, however, it is indicated that at least 2 weeks must elapse between the time of application and the time of planting the crop depending largely on the rainfall during this interim. In tests where there was a dearth of rainfall Sweet (9) indicated that a 4 to 6 weeks interim was necessary to dissipate the toxic agent from the soil. He used 7.5 pounds of 2,4–D per acre and applied it as a spray, although it has been applied as a dust and worked into the soil with a Rototiller (10). Apparently 2,4–D is toxic to germinating seedlings of grasses.

Three different herbicides have been used in the work reported here which include Sovasol No. 5 (Stoddard Solvent), Essoheat Medium (fuel oil) and Dow Contact Herbicide.

Stoddard Solvent is a naphthenic oil used for dry cleaning clothes and thinning paint. It has been found that this oil has remarkable herbicidal qualities and is selective for umbelliferous crops (7). It has an acute toxicity for weeds while they are small and this is true for most plants except for the umbels and ragweed. The oil has a relatively high flash point but it evaporates rather rapidly and leaves no toxic residue in the soil. Applied at the rate of 80 to 100 gallons per acre Stoddard Solvent makes an admirable herbicide to use for pre-emergence weed killing. It is advisable to use this material when the humidity of the air is high so that the oil will not evaporate too quickly.

Diesel or fuel oil is also very useful for pre-emergence weed killing, provided the application is kept below 80 gallons per acre; 60 gallons is recommended.

Dow Contact Herbicide is a liquid plant toxicant containing dinitro-ortho-secondary butyl phenol in oil. It was found that a 1 to 1½ per cent solution of this material in water provided an efficient pre-emergence spray while a 3 per cent spray was harmful to all crops except snap beans. This was applied at 60 to 80 gallons per acre.

RESULTS

Nine different vegetables were weeded by pre-emergence sprays during the summer of 1946 including turnip, parsnip, carrot, bean, sweet corn, seed and set onions, lettuce, beet and spinach. The tests were repeated three times and the most successful results were attained from the following procedure:

The land was fitted in the usual manner and then irrigated with about ¼ inch of water or enough to encourage quick germination of weed seeds. The plots were then allowed to lie idle for 7 days after which the crops were planted. Daily temperatures during these periods averaged about 70 degrees F. The plots were sprayed with the herbicides on succeeding days after the crops were planted. The turnips germinated so quickly that it was necessary to spray them not later than 1 day after seeding. Where 2 or 3 days elapsed between seeding and spraying, good results were obtained with all the other crops mentioned. Where the land was sprayed 5 days after seeding, however, the crops were either killed or damaged so badly that a very poor stand resulted. During periods of lower temperatures, as is the case in the culture of set onions, it is obvious that the period between planting and spraying might be extended with no ill effects. Crafts has stated that pre-emergence sprays should not be applied when the soil temperature rises above 90 degrees F during the day (3).

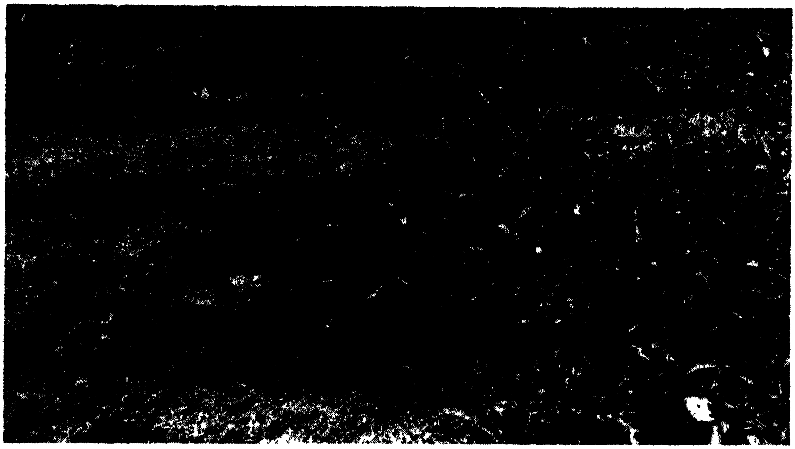

FIG. 1. Left: Showing the condition of an onion plot 5 weeks after spraying with Stoddard Solvent as a pre-emergence herbicide. Right: Showing the unsprayed portion of the plot. The weed population was made up largely of crab grass, purslane, galensoga and pigweed. The plots received no cultivation or hand weeding.

The plots which had been sprayed with Stoddard Solvent were uniformly free of weeds and many observers concluded that this was a most admirable herbicide to use for pre-emergence spraying (Fig. 2). In fact, several commercial crops of spinach were weeded in this manner and grown to maturity without any cultivation or other weed control measures being necessary. Crops of beans, corn, onions, lettuce, spinach and beets in the experimental plots were relatively free of weeds for a period of 6 weeks after they had been sprayed. The fuel oil and contact herbicide also gave very good results and while the cost of these materials was cheaper than Stoddard Solvent it appeared that the hazard of crop injury was a trifle greater than where the latter material was used. These materials were effective against annual weeds in asparagus beds but all of the spears must be harvested prior to spraying to prevent their injury.

DISCUSSION

Although pre-emergence spraying does not keep crops free from weeds, it does get rid of the important early hand weedings and plant competition.

It is rather doubtful whether vegetable growers would sanction a delay in planting after fitting the land as was the case in these experiments. By planting seeds of the crop slightly deeper than usual, however, crop emergence is delayed somewhat and the weed seedlings would have a chance to develop prior to crop emergence. This practice would allow the pre-emergence technique to be followed to good advantage. Where crops are planted deeper than ordinarily recommended a heavier rate of seeding is generally necessary to obtain a perfect stand and seed treatment with appropriate fungicides is increasingly important.

This practice necessitates more careful planning of seed bed preparation and time of planting than the usual procedure. It is fairly obvious that pre-emergence weed control is not a thing for the careless operator. Exact knowledge is required of the number of days needed by crops to germinate under various conditions. Schedules will vary according to the crop, prevailing temperatures, soil type, planting depth, soil moisture, and so on.

To delay the application of the spray for 1 or 2 days may mean that other weed control measures must be used since a weed killer may seriously damage or ruin a crop if applied after the seedlings have broken through the soil. This limits the possible time for safe and effective spraying to a few days and inclement weather often upsets an otherwise carefully worked out schedule for pre-emergence spraying.

SUMMARY

It was found that a number of chemicals and especially Stoddard Solvent were very useful as pre-emergence herbicides for vegetable crops. This offers a quick and very effective means of eliminating weed competition and may supplant hand weeding during the early growth of some vegetable crops.

Those who contemplate the use of pre-emergence weed control for the first time, at least, should experiment on a small scale with their crops to become familiar with the various operations involved.

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The Use of Oil Sprays as Selective Herbicides for Carrots and Parsnips III[1]

By WILLIAM H. LACHMAN, *Massachusetts State College, Amherst, Mass.*

IN several previous publications the author described the use of "Stoddard Solvent" as a means of controlling weeds in fields of carrots and parsnips (7, 8, 9). This has been an outgrowth of the method used in California where a light fuel oil, commonly termed stove oil or stove top, has been widely used for weeding carrot fields (3, 5). Stove top is not available in large quantities in the East, hence, the use of other materials. It is the purpose of this paper to present the results of recent findings using Stoddard Solvent as a selective herbicide.

RESULTS AND DISCUSSION

Stoddard Solvent has been used for chemically weeding carrot and parsnip fields on a rather large scale for two years. It is applied without dilution at the rate of about 100 gallons per acre. During 1945 about 500 acres and in 1946 about 1,000 acres of carrots and parsnips were sprayed in Massachusetts. Of the various proprietary brands of Stoddard Solvent that were sold in 1946, for spraying carrots, 100,000 gallons of one brand were sold in New York State alone.

This oil is a highly refined, straight-run petroleum naphtha with an initial boiling point of slightly over 300 degrees F, and a final boiling point of 385 to 395 degrees F. It is a typical "mineral spirits", "paint thinner", and "dry cleaners' naphtha". It has a flash point of 100 degrees F or higher, contains 15 per cent by volume of aromatics and 0.6 per cent by volume of olefines. Ragweed and wild carrot are not affected by the oil, but susceptible plants are killed very rapidly.

They began to wilt a few minutes after spraying and are dead within a few days. Crafts (3) has called this mode of action acute toxicity. Crafts and Reiber state that the aromatic hydrocarbons and olefinic compounds are largely responsible for oil injury (4). The comparatively small content of olefinic compounds in Stoddard Solvent would lead one to believe that the aromatic content of this oil was responsible for its herbicidal properties. Recent work indicates that other ingredients may also contribute to toxicity of petroleum compounds as shown by the ability of low aromatic and olefinic oils to kill weeds with good selectivity (10).

WHEN TO SPRAY

Best results are usually attained from spraying Stoddard Solvent on carrots and parsnips when they are in the 1- to 4-leaf stage and when the weeds are small (not over 2 inches tall). Relatively little damage to the crop is caused when the oil is applied on a clear day when the temperature is below 80 degrees F. Crafts (3) states that young carrots sprayed with stove oil have been killed by frost, whereas unsprayed carrots are frost resistant.

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[1] Contribution No. 613 of the Massachusetts Agricultural Experiment Station.

The resistance of carrots and parsnips to the oil is probably physiological in nature for they are wetted by the spray and during the greater part of their early growth period these crops are not appreciably damaged. Spraying young carrot seedlings in the early cotyledonous stage, just as they emerged from the soil, however, resulted in a reduction in the stand from 28 to 6 plants per foot of row. In a great many tests carrots that were sprayed in the later cotyledonous stage, that is just previous to the appearance of the first true leaves, displayed characteristic resistance to damage from the oil.

Spraying with Stoddard Solvent usually results in a slight over-all bleaching effect of the green color in the carrot plants. This bleaching effect does not appear to be associated with any damage to the plants and the darker color that is characteristic of unsprayed plants usually returns within 10 days.

TOXIC EFFECTS OF THE OIL

Sometimes one or more of the older leaves in the outermost whorl of young carrot plants becomes rather seriously scorched or burned as a result of spraying with Stoddard Solvent. It has been rather definitely established that this damage is most apt to occur after the plants have been sprayed while wet from a rain or heavy dew. In order to study this problem, young carrots were thoroughly wetted in several tests with water from a sprinkling can during the afternoon of bright sunny days. The plants were then sprayed immediately with Stoddard Solvent. The carrots on these plots were not damaged any more than those on the unsprinkled plots. It is evident that other factors such as humidity, transpiration rate, light, and so on, play a part in this problem. Crafts says that if the plants are wet at the time of spraying he applies the oil at high pressures with the object of blowing the excess moisture from the plants (4). In this connection Beare, using kerosene sprays, found that the larger droplets of spray resulting from low pressure increased the degree of burning to carrots (2). It is interesting to note that when Stoddard Solvent was emulsified at strengths of 25 per cent and 50 per cent its weed killing properties were seriously reduced, but its tendency to burn and scorch the leaves of young carrot plants was greatly increased.

The author has noted that the oil may scorch the plants when applied on clear but extremely hot, quiet days and Crafts also found that toxicity of stove oil both to weeds and to the crop is increased by heat (3). He says that, "spraying while temperatures are above 90 degrees F may be dangerous and should be avoided". Crafts also found that some of the oils which ordinarily did no damage to carrots became quite toxic and produced considerable crop damage after storage in closed containers for about a year (4). In two different tests Stoddard Solvent stored in steel drums for a period of 10 months was no more toxic than samples obtained direct from the refinery.

EFFECT ON YIELD AND QUALITY

In the experimental plots as well as in large scale commercial plantings, spraying with Stoddard Solvent has not caused either an increase or decrease in yields. During 1946 a definite check was made to ascertain the effects of the oil on the yield and grade of carrots. The variety Chantenay was planted on May 20 and the treated rows were sprayed on June 14 and 25. These plots were interspersed with check plots as well as appropriate guard rows. The treated and check plots were replicated six times. The carrots were harvested November 1 as cut-off carrots. There was a difference of only 113 pounds per acre between the treated and the check plots and the difference was in favor of the check.

According to Students "t" test for determining the significance of difference between two means, the odds were about 2 to 1 that the difference was due to the treatment. This difference is certainly too small to be of significance. These results corroborate the findings of Warren and Hanning (13) and Grigsby (6). Some results from Australia, however, have shown that spraying carrots with kerosene, resulted in increased yields (1).

Extreme care must be exercised in spraying carrots with stove top because this material often causes off flavor or an oily taste after cooking, particularly if the plants are sprayed after they developed past the 4-leaf stage. Crafts states that a period of 75 to 90 days must elapse from spraying to harvest to dissipate the oily flavor from carrots sprayed with stove top (3). With Stoddard Solvent the flavor is dissipated from the roots much more quickly than this (7, 8, 12, 13). Of the carrots harvested from 1500 acres in Massachusetts during 1945 and 1946 we have had no rejections of sales nor adverse comment on the flavor of roots due to oily flavor.

RESPONSE OF VARIOUS CROPS

Sixteen varieties and strains of carrots were sprayed three times with Stoddard Solvent at the Experiment Station during 1946 and most of the common varieties were cultivated and sprayed by vegetable growers in this State. There was no apparent differential susceptibility among the varieties that were sprayed.

Of the various umbelliferous crops tested, carrots displayed the greatest resistance to damage from Stoddard Solvent. Older carrot plants, however, are susceptible to the oil particularly after the roots attain a diameter of $^{1}/_{4}$ to $^{3}/_{16}$ inch. When sprayed after this stage the oil often destroys the heart of the plant and severe injury may envelop the core of the carrot root. Carrots affected even slightly in this manner keep poorly when placed in cold storage.

Parsnips may be sprayed with relatively little injury up to the 4-leaf stage but it is not advisable to spray them in their later stages of development. Raphael, using power kerosene, has stated, "in parsnips, good weed control was associated with damage to seedlings in the 3-leaf stage and with severe injury in later stages" (11). A few farmers noted a considerable amount of core burning or necrosis in parsnip roots which resulted from spraying the plants when they were about 12 inches tall and the roots about $^{3}/_{8}$-inch in diameter.

Small celery seedlings grown in out-of-door seedbeds tolerate applications of Stoddard Solvent but if sprayed after they develop to the size for transplanting they are most often damaged beyond recovery. Grigsby, however, working in Michigan, sprayed celery twice after it had been transplanted without any apparent injury (6).

Other crops that are not appreciably injured by the oil if sprayed when they are small include parsley, fennel, caraway, coriander, dill, celeriac and parsnip rooted parsley. Natural seedings of some of these crops, particularly dill in carrot fields, may provide a weed menace that cannot be combatted with Stoddard Solvent.

Injury to the growing point of the various umbels resulting from Stoddard Solvent spray seems to be somewhat associated with the development of the characteristic hollow or groove on the upper side of the leaf petioles as well as the rather upright pose of the leaves assumed at about this time. These factors appear to be responsible for directing the oil down to the growing point of the plants where the rate of evaporation is low and here the oil damage is at the maximum. Obviously the plants should not be sprayed after they have reached this stage of development.

SUMMARY

Continued research and large-scale commercial use indicate that Stoddard Solvent provides an admirable selective herbicide for members of the umbelliferae family if applied properly, and, while the plants are small. High air temperatures and moisture on the leaves at the time of spraying may induce some plant injury, however. Where adequate precautions have been observed the yield of crops has not been affected adversely by spraying with Stoddard Solvent.

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Weed Control in Cannery Peas Using Dinitro Sprays[1]

By G. F. WARREN and K. P. BUCHHOLTZ, *University of Wisconsin, Madison, Wis.*

WORKERS in some of the western states (5, 6, 8) have reported the successful use of Sinox[2], a preparation containing 30 per cent sodium dinitro ortho cresylate as a selective spray to control certain weeds in cannery and field peas. The addition of a small amount of an acid salt to the Sinox spray was found by Harris and Hyslop (5) to greatly increase its effectiveness. Crafts and Reiber (2) have reported the results of further studies on this subject and have termed the effect "activation". The salt most commonly used as an activator for Sinox is ammonium sulfate. More recently (1, 4, 7) a new dinitro, the ammonium salt of dinitro ortho secondary butyl phenol has been used successfully on peas. The commercial preparation of this material is sold as Dow Selective Weed Killer.[3] It is a liquid and is used without an activator.

Harris and Hyslop (5) working in Oregon reported good control of Russian thistle, vetch and nightshade and no injury to peas by using 8 to 10 pounds each of Sinox and ammonium sulfate in 100 gallons of water per acre. Litzenberger, *et al.* (6) working in Montana reported yield increases in peas of 173 to 264 per cent where weed infestation was heavy by using a Sinox spray. They recommend 1 gallon of Sinox with 2 pounds of activator in 100 gallons of water applied at 80 gallons per acre. On the other hand, Barrons and Grigsby (1, 4) working in Michigan reported considerable injury to peas when ammonium sulfate was used with a 1 per cent Sinox solution, and recommended its use without an activator. They also obtained satisfactory weed control and no reduction in yield of peas with Dow Selective Weed Killer and suggested a concentration of 3 pints per 100 gallons. However, weed infestation was light in all their experiments and none of the spray treatments resulted in any increase in yield over the checks. Warren (7) working in Wisconsin also reported good results with Dow Selective. He noted considerable injury with a 1 per cent Sinox solution containing an activator, but Sinox without an activator was not included in his experiments.

The purpose of the experiment reported here was to determine the appropriate concentration of these dinitro sprays to control annual weds under Wisconsin conditions and the effect of the sprays on the yield of peas when heavily infested with weeds.

MATERIALS AND METHODS

The experiment was conducted in 1946 in a commercial field of Pride peas heavily infested with weeds in Dodge County, Wisconsin. Lambs-quarters *(Chenopodium album)* made up about 90 per cent of the weed population. The spray materials used were Sinox, Dow

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[1] Published with the permission of the Director of the Agricultural Experiment Station.

[2] Manufactured by Standard Agricultural Chemicals, Inc., Hoboken, N. J.

[3] Manufactured by the Dow Chemical Company, Midland, Michigan.

Selective Weed Killer and ammonium sulfate. These were applied in water solutions with knapsack sprayers fitted with Spraying Systems No. ¼ T8004 nozzles[4] giving an 80 degree fan-shaped spray.

Four series of seven plots, each one-half square rod ($^1/_{320}$ acre) in area, were laid out with 2-foot alleyways cut between them. The peas were sprayed between 1:00 and 3:00 p. m., June 11, and were 6 to 8 inches tall at this time. The temperature at time of spraying was 83 degrees F, the relative humidity 72 per cent, the sky about 50 per cent overcast, and the soil wet from rain the day before. All sprays were applied at the rate of 100 gallons per acre. Harvesting was done July 10 and at this time the peas were at a good canning stage, being well developed yet still of fancy quality.

The procedure in harvesting and vining is of particular interest because of the small amount of labor involved. The vines were cut with a mowing machine equipped with standard pea harvesting attachments, stopping briefly between each plot to clean off the cutter bar. The vines from each plot were then placed in extra large bags and hauled to a commercial vining station. Vining was done in the standard commercial manner, approximately 5 minutes being required for each lot. The shelled peas were freed of pods and foreign material by screening and hand picking and then weighed to an accuracy of one gram.

The plot size in this experiment was much smaller than has ordinarily been considered necessary when a commercial viner is used. Davis (3) states that to obtain reliable results with a commercial viner, 80 to 100 pounds of shelled peas are required. To be assured of this quantity of peas, he suggests a minimum plot size of $^1/_{20}$th acre. In our experiment, the weight of shelled peas from individual plots varied from approximately 3 to 8 pounds. However, the vines coming out of the machine were carefully checked and found to contain practically no peas and running the viner several minutes longer between lots showed that virtually 100 per cent were shelled in the 5 minutes allowed. Therefore, the procedure appeared to be highly accurate.

This method is much simpler and faster than that proposed by Davis (3) which involved vine sampling, hand picking of pods and the use of a small huller. In our experiment, all work was done by three men, except for mowing the peas. The entire harvesting, hauling, vining and weighing of shelled peas on the 28 plots was done in a half day and the viner was in use less than 2½ hours. From experience gained in this and a supplementary experiment, the writers believe that ½ square rod plots are large enough except where a greater quantity of shelled peas is needed for processing studies. They feel that if it is desired to increase the accuracy of canning pea experiments, it can be done much better by using a larger number of replicates than by increasing the plot size.

RESULTS

The data presented in Table I give the results of this experiment. Plots treated with Dow Selective at all of the concentrations used gave

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[4] Manufactured by Spraying Systems Company, Chicago, Illinois.

TABLE I—EFFECT OF DINITRO SPRAYS ON WEED CONTROL AND THE YIELD OF CANNERY PEAS

Material	Quantity Per 100 Gallons		Estimated Per Cent of Weeds Killed	Yield of Shelled Peas (Pounds Per Acre)
	Dinitro (Pints)	Ammonium Sulfate (Pounds)		
Check	–	—	—	1,249
Sinox	8	1.5	90	1,601
Sinox	4	1.5	80	1,594
Sinox	8	—	50	1,454
Dow Selective	2	—	30	1,784
Dow Selective	3	—	60	2,110
Dow Selective	4	—	90	2,250
Least difference for significance				
5 per cent level				293
1 per cent level				403

yields of peas much higher than the check plots. The differences are significant at the 1 per cent level. Moreover, the 3- and 4-pint dilutions resulted in higher yields than the 2-pint concentration, the difference being significant at the 5 per cent level. On the other hand, the increase in yield with the Sinox sprays was not so striking. When the ammonium sulfate activator was used, both the 4- and 8-pint concentrations gave yields significantly higher than the check at the 5 per cent level, but not as high as any of the Dow Selective sprays. When used at the 8-pint dilution without the activator, Sinox did not produce a significant increase in yield.

The figures for estimated per cent of weeds killed show a fair correlation with yield *within* the Dow Selective and Sinox treatments but not *between* them. In all cases, plots treated with Dow Selective gave considerably higher yields than those treated with Sinox when the per cent of weeds killed was comparable. The reason for this may be due to greater injury to the peas by the Sinox sprays. Although it was not possible to obtain accurate notes on pea injury in this field due to the complicating effects of dry weather, careful observations were made on a supplementary experiment. In the latter experiment, Sinox at the 8-pint dilution containing ammonium sulfate resulted in severe injury. The 4-pint concentration plus the activator gave less injury, but still slightly more than any of the Dow Selective Sprays. This is in agreement with results reported by Barrons and Grigsby (1, 4) and by Warren (7). On the other hand, Harris and Hyslop (5) and Litzenberger *et al.* (6) reported good results on peas using an activator with similar concentrations of Sinox. The greater success obtained by these latter workers may be due to the generally drier weather conditions under which they worked.

In addition to the observed burning injury, there may be a slow poisoning effect which cannot be readily seen on peas. Such an effect was observed on the lambs quarters plants. On plots showing the lower percentages of kill, the weeds were stunted, the leaves being smaller and the plants shorter. This was noticeable both with Sinox and Dow Selective treatments. If such a poisoning effect exists on peas, and if it is more severe with Sinox than Dow Selective, this might explain the discrepancy in pea yields with comparable weed control.

SUMMARY

The results of an experiment are reported in which cannery peas that were heavily infested with weeds were sprayed with various concentrations of the following dinitros: Sinox (sodium dinitro ortho cresylate) and Dow Selective Weed Killer (ammonium salt of dinitro ortho secondary butyl phenol).

Plots treated with Dow Selective Weed Killer gave large and highly significant increases in the yield of shelled peas compared with untreated plots, the highest yields being obtained when either 3 or 4 pints of Dow Selective Weed Killer were used per 100 gallons of water. Plots sprayed with Sinox at certain concentrations yielded significantly greater than the checks but not as high as any of the plots sprayed with Dow Selective. The poorer results with Sinox compared with Dow Selective appeared to be due to greater injury to the peas since, at the higher concentrations used, weed control was good with both materials.

In this experiment the ½-square-rod plots used were considerably smaller than that commonly thought necessary by other workers. Use of plots of this size gave results, insofar as could be determined, as reliable as might be expected with the use of larger plots.

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Preplanting Sprays to Control Weeds in Nursery Stock

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

Perennial weeds often become established in older blocks of nursery stock and are difficult to eradicate. Quack-grass, *Agropyron repens,* is one such weed; bindweed, *Convolvulus arvensis,* is a second. Control of the latter weed has already been described (5, 3) using 2,4–D sprays on the foliage. Preliminary experiments with cuttings from quack-grass indicated that dipping them or soaking them in solutions of 2,4–D greatly reduced the growth of young plants from such cuttings. This applies also to gladiolus cormels. Ennis (2) reported drastically reduced yield in potatoes from applications of 2,4–D and the ammonium salt of 2,4,5–trichlorophenoxyacetic acid when the applications were approximately ten times the amount employed for standard weed killing practices.

The purpose in the present experiments was to determine the possibility of applying 2,4–D as compared to other soil sterilants for eradication of fleshy rooted weeds by contact with rather than by translocation to the roots. It was also the purpose to determine the effect of 2,4–D as a soil sterilant on such evergreens as Taxus when the sterilant may come in contact with actively growing roots.

A field heavily infested with quack-grass was plowed and fitted in

TABLE I—Stand of *Agropyron repens* Present December 1 in Plots Treated with Herbicides after Fitting the Land in August

Herbicide 10 by 10 Plot	Gallons Used/Plot	Agropyron Repens				Other Weeds			
		O*	A	B	C	O	A	B	C
Ammonium sulfocyanate	1	H	M	O	O	M	M	O	O
	5	H	H	O	O	M	M	O	O
AtlasA . .'	1	M	L	M	P	M	H	L	L
	5	H	L	P	P	H	M	L	O
Ammate	1	M	L	M	P	M	H	L	L
	5	L	M	L	P	H	H	L	L
Cyanamid dust	1	L	M	L	L	M	M	M	M
	5	M	L	L	P	M	M	M	L
Esteron	1	H	P	P	O	M	L	P	O
	5	M	L	P	O	M	P	P	O
Stantox 20...	1	H	L	O	O	M	P	O	O
	5	H	L	O	O	M	P	O	O
Methyl ester....... ..	1	M	L	L	P	M	L	P	O
	5	M	M	L	L	H	M	M	M

*O—Untreated plot.
A—Lowest amount of herbicide 10 by 10 plot.
B—Medium amount of herbicide 10 by 10 plot.
C—Largest amount of herbicide 10 by 10 plot.
Amounts of concentrate used per 10 by 10 plot are as follows:

Herbicide	*A*	*B*	*C*
Ammonium sulfocyanate	½ pint	1 quart	1 gallon
AtlasA 40 per cent sodium arsenite	50 cc	500 cc	1000 cc
Ammate	22 grams	45 grams	100 grams
Cyanamid dust	1 pound	5 pounds	10 pounds
Esteron	110 cc	220 cc	1100 cc
Stantox 20	110 cc	220 cc	1100 cc
Methyl ester Baker	120 cc	250 cc	500 cc

late July. Herbicides of a sterilant type were used to compare their effectiveness with 2,4–D in eliminating quack-grass. Areas 10 by 10 feet were used as plots and after treatment, bare root plants of *Taxus media Hicksii* and 1 year potted cuttings of *Taxus cuspidata* were planted by inserting a spade, moving it back and forth, inserting the plant and then closing the hole by stepping against the sides. Test crops of red kidney beans and of Victory oats were planted August 7 and September 7. Plots remained uncultivated through the remainder of the season. Ratings made on quack-grass populations in November are given in Table I. The populations are listed as none (0), a few plants present (P), light infestation (L), moderate (M), and heavy (H).

Of the herbicides tested in the amounts used Ammonium sulfocyanate and Atlas A were as effective as 2,4–D. At the lowest concentrations (A) 2,4–D more consistently reduced the stand of quack-grass. This applies also to other weeds which included primarily lambs quarters, *Chenopodium album,* sour dock, *Rumex Acetosa,* old witch-grass, *Panicum capillare,* and ragweed, *Ambrosia artemisiifolia.*

The toxicity of ammonium sulfocyanate at the concentrations used for effective control of *Agropyron repens* is too high for *Taxus media Hicksii* and *Taxus cuspidata.* Atlas A is likewise too toxic except for

TABLE II—PER CENT MORTALITY IN *Taxus media Hicksii* (AND *Taxus cuspidata* LINING OUT STOCK PLANTED IN SOIL TREATED WITH STERILANT HERBICIDES IMMEDIATELY AFTER PREPARATION AUGUST 1

Herbicide	Gallons 10 by 10 plot	Taxus media Hicksit				Taxus cuspidata			
		O*	A	B	C	O	A	B	C
Ammonium sulfocyanate	1	0	63	100	100	0	36	87	100
	5	12	12	100	100	6	0	100	100
AtlasA	1	25	0	100	100	0	6	6	75
	5	0	0	75	100	0	0	25	60
Ammate	1	0	50	37	50	0	6	12	68
	5	25	12	37	75	12	36	66	80
Cyanamid dust	1	0	12	100	60	0	0	6	88
	5	0	12	75	100	0	6	37	66
Esteron	1	12	25	0	75	0	18	0	25
	5	0	0	0	37	0	0	0	18
Stantox 20	1	25	25	0	0	0	31	6	12
	5	0	0	0	0	6	43	31	19
Methyl ester	1	0	0	25	12	0	19	12	6
	5	0	0	0	12	0	12	12	6

*O—Untreated plot.
A—Lowest amount of herbicide 10 by 10 plot.
B—Medium amount of herbicide 10 by 10 plot.
C—Largest amount of herbicide 10 by 10 plot.
Amount of concentrate used per 10 by 10 plot as follows:

Herbicide	*A*	*B*	*C*
Ammonium sulfocyanate	½ pint	1 quart	1 gallon
AtlasA 40 per cent sodium arsenite	50 cc	500 cc	1000 cc
Ammate	22 grams	45 grams	100 grams
Cyanamid dust	1 pound	5 pounds	10 pounds
Esteron	110 cc	220 cc	1100 cc
Stantox 20	110 cc	220 cc	1100 cc
Methyl ester Baker	120 cc	250 cc	500 cc

Taxus cuspidata where the roots were enclosed in a ball of earth at planting time. The relative permanence (9) of the Atlas A (arsenite) in the soil may result in further loss of plants in 1947.

2,4–D salts give good weed control and at the concentrations used were not toxic to the Taxus. In other plots where double and five times the present maximum was used for treating the soil, Taxus showed prohibitive mortality. When sprayed on the foliage in established plantings even these high amounts (250 pounds per acre) were not immediately fatal to Taxus though broad-leaf weeds were eradicated promptly.

Other growth regulators have been used in transplanting evergreen nursery stock. Dusts were used in some cases; in others the roots of seedlings were dipped or soaked in concentrations of up to 1000 parts per million. Ostrom *et al* (7) and Maki and Marshall (4) summarize this work. They found some stimulation of rooting but increased mortality when the concentrations approximated 100 parts per million. In these cases the 2,4–D was applied directly to the roots and may explain the low mortality when 2,4–D is applied to the soil surface.

This is in agreement with preliminary tests both in the greenhouse and on small 3 by 3 feet plots outdoors. De Rose (1), also Mitchell and Marth (6) have reported persistence of 2,4–D in soils for long periods of time. Grains were not seriously affected but mustard was reduced in stand 6 months and more after treatment with lower amounts than used in the present tests. The 2,4–D, however, was mixed with the soil at the time of application.

TABLE III—GROWTH OF TEST CROP OF RED KIDNEY BEANS FOR RESIDUAL HERBICIDE EFFECT THIRTY DAYS AFTER APPLICATION (JULY 31 TO SEPTEMBER 7, 1946)

Herbicide	Gallons 10 by 10 plot	Test Aug 5				Test Sep 7			
		C*	A	B	C	O	A	B	C
Ammonium sulfocyanate	1	0	+	+	+	0	+	+	+
	5	0	0	+	+	0	0	+	+
AtlasA..... . .	1	0	+	0	+	0	0	+	+
	5	0	0	+	+	0	0	+	+
Ammate....... .	1	0	(+)**	(+)	(+)	0	0	0	(+)
	5	0	(+)	(+)	(+)	0	0	0	0
Cyanamid dust........	1	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
Esteron..	1	0	+	+	+	0	0	+	+
	5	(+)	+	+	+	(+)	+	+	+
Stantox 20..	1	0	+	+	+	0	+	+	+
	5	0	+	+	+	0	+	+	+
Methyl ester..........	1	0	+	+	+	0	0	+	+
	5	0	0	+	+	0	0	+	+

*O—Untreated plot.
A—Lowest amount of herbicide 10 by 10 plot.
B—Medium amount of herbicide 10 by 10 plot.
C—Largest amount of herbicide 10 by 10 plot.
**Indicates effect of 2,4-D evident in any recognized degree of foliage distortion as well as dwarfing plants and reduced stand.

Using red kidney beans as indicator plants, it would appear that

2,4–D remains in the soil for at least a month in adequate amounts to prevent growth in some cases and to seriously distort the growth of others in the same sample of 10 beans.

Victory oats used as a test crop for 2,4–D are less sensitive than red kidney beans. Failure to germinate and stunted growth were, however, found in oats as well as in beans in the first planting but not in the second planting to any marked degree. Ammonium sulfocyanate and Atlas A produced injury in low germination and stunted growth of oats after a month's time from application.

SUMMARY

2,4–dichlorophenoxyacetic acid used in the range of 15 to 75 pounds to the acre at the time of plowing gives promise of eradicating quackgrass and other perennial weeds whose roots constitute a menace from resprouting. *Taxus media Hicksii* and *Taxus cuspidata* were not seriously damaged at the time of planting when set in soil treated with 2,4–D. 2,4–D applied in amounts up to 37½ pounds per acre remains sufficiently active for 2 months at least for detection with red kidney beans but not with Victory oats.

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The Effect of 2,4–Dichlorophenoxyacetic Acid Applied at the Time of Seed Germination in Reducing Stands of Annual Grasses

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

The reduction in stand of grasses when the soil is sprayed after sowing has been pointed out previously (4, 5, 6). Soaking seeds in solutions of growth regulators or dusting them has reduced germination (2, 3). Since crab grass *(Digitaria Ischoemum)* is a serious lawn weed, tests were set up in an area which exhibited a dense stand in the autumn of 1945. Spraying was done in early June at the time young crab grass plants could first be discerned. Counts taken in early July indicated populations in excess of 200 seedlings per square foot in a mixed stand of wild white clover and Kentucky blue grass. A commercial formulation of amine salt 2,4–D was used in concentrations of 1000 ppm, 2000 ppm and 3000 ppm. Two volumes, ½ gallon to 100 square feet and double that amount (1 gallon) was applied to insure the soil surface receiving adequate volume to moisten it thoroughly. Plots 10 by 10 feet were used and 6 weeks after spraying the area received 2 pounds of 5–10–5 fertilizer for each plot. Weed counts made a month after application of the 2,4–D were as follows in Table I.

TABLE I—Stand of Crab Grass, *Digitaria Ischoemum*, July 1, 30 Days After Application of 2,4–D (Data Indicate Number of Plants per Square Foot)

Pounds Per Acre Amine Salt 2,4-D	Dense Stand Volume Per Plot		Moderate Stand Volume Per Plot	
	½ Gal	1 Gal	½ Gal	1 Gal
0	100	—	100	—
Plants*	172	—	85	—
1.5	41	—	27	—
3	97	57	6	27
4.5	21	—	2	—
6	—	8	—	4
9	—	0	—	0

*Data given with check rated at 100, based on actual count, average of three counts per plot. This figure is stated for checks only.

Results

Crab grass populations were reduced sharply by concentrations of 3000 ppm applied at ½ gallon rate or lower concentrations at a larger volume. Clover was seriously injured in all but the lowest concentrations; since it was present in abundance and its removal opened up large areas of bare soil. Dandelion and plantain were also present prior to spraying. Fertilizer was applied to stimulate the growth of the Kentucky blue grass which remained apparently uninjured as did small colonies of bent grass and red fescue.

Barnyard-grass, (Echinochloa Crus-galli):—A location known to be heavily infested with this weed was plowed and prepared for planting. Experimental blocks 3 by 3 feet were marked out. Treatment was made on three dates.

The applications were made to young seedlings to the 2-leaf stage and to the remainder of the weeds invading the areas, quack-grass, *Agropyron repens,* being the principal weed. Counts for populations of barnyard-grass were made 30 days after treatment. No additional growth was noted during the remainder of the season.

TABLE II—REDUCTION IN STAND OF BARNYARD-GRASS, *Echinochloa Crus-galli,* FROM 2,4-D SPRAYS DURING THE PERIOD OF GERMINATION

Amount of Amine Salt, 2,4-D Per Acre in 200 Gallon Volume	Applied May 15 Stand of Weeds	Applied Jun 4 Stand of Weeds
0	100	100
0 Count Square feet	95 plants	41 plants
1.5	157	57
3	78	29
4.5	71	29
6	65	22
7.5	23	22
15	—	—
22.5	—	—
37.5	—	—

When soil is sprayed and left undisturbed by cultivation, 2,4–D proved to be effective in reduction of barnyard grass when applied at the rate of 5000 ppm. A rainfall of ½ inch following application of 2,4–D May 15 either leached or dispersed the 2,4–D so that no serious interference with a stand of grass was noted till the 5000 ppm treatment was reached. In this case reduction of stand is similar to that obtained under dry weather spray conditions.

Preliminary tests indicate that amine salts of 2,4–D used in concentrations of 5000 ppm and higher reduce the stand of old witch-grass *(Panicum capillare)* in six plots, July applications, and of annual blue grass *(Poa annua)* in six plots, October applications in six plots in areas where untreated plots have moderate to abundant populations of these grasses.

Since sprays of 5000 ppm and more are likely to injure permanent lawn grasses when applied in volumes of 200 gallons to the acre, more flexible control might be obtained from repeated sprays of low concentrations or by using lower concentrations together with higher volume in a single application at an appropriate time.

It has already been pointed out (6) that 2,4–D may be applied successfully for the control of dandelion and plantain through the period May to October without injury to common lawn grasses. In 1946 2,4–D has been used on some 500 plots at several locations in New York State. March applications included some 15 commercial formulations and resulted in slight discoloration of lawn grasses, also in both slower and less complete kill of broadleaf weeds. Injury to lawn grass was recorded from midsummer applications on sandy soils of Long Island where concentrations of 3000 ppm and more were used. October and November applications to Kentucky blue grass sod (Ithaca) resulted in turf injury only in concentrations over 5000 ppm. The use of fertilizers in combination with the 2,4–D appeared to reduce the intensity and shortened the duration of discoloration. Under lawn conditions control of annual weeds by a single application of 2,4–D at any optimum time offers one possibility for reducing stands of annual weeds.

Victory oats were used as a test crop for an area plowed in July and sprayed after the soil had been prepared for planting. Seeds were sown on several dates by making a slit in the soil and inserting the grains then refirming the soil in place. No attempt was made to measure the growth of the oat crop through some of the first planting reached the seed stage. Preliminary tests in which seed were dipped or soaked in solutions of up to 1000 ppm indicated that in no case did such treatment completely prevent germination of the oats. Concentrations of 500 ppm and more reduced growth as measured by height of plant. Soaking oats in similar solutions for 3 hours time caused reduction in height at as low as 250 ppm. Severe injury and death of the plant at the end of 2 weeks time also occurred. 2,4–D acid in Carbowax, also 2,4–D methyl ester (Esteron) produced severe injury to root and top at 50 ppm. Other herbicides including arsenicals, employed did not induce serious injury.

TABLE III—STAND OF VICTORY OATS IN FIELD PLOTS TREATED WITH HERBICIDES AT TIME OF PLOWING (JULY 30, 1946)

Herbicide	Gallons 10 by 10 Plot	Test Planting Aug 5				Test Planting Sep 7			
		O*	A	B	C	O	A	B	C
Ammonium sulfocyanate	1	N**	O	O	O	N	N	I	O
	5	N	N	O	O	N	N	O	O
Esteron	1	N	I	N	O	N	N	N	I
	5	N	N	O	O	N	N	N	N
Sodium arsenite	1	N	I	O	O	N	N	O	I
	5	N	N	O	O	N	N	I	I
Stantox 20	1	N	O	O	O	N	N	N	N
	5	N	O	O	O	N	N	N	N
Ammate	1	N	N	N	N	N	N	N	N
	5	N	N	N	I	N	N	N	N
Methyl Ester (B)	1	N	N	O	O	N	N	N	N
	5	N	N	N	N	N	N	N	N
Cyanamid	1	N	N	N	N	N	N	N	N
	5	N	N	N	I	N	N	N	N

Amount concentrate used per 10 by 10 plot as follows:

Herbicide	*A*	*B*	*C*
Ammonium thiocyanate (commercial)	½ pint	1 quart	1 gallon
Esterol (methyl ester 2,4-D)	110 cc	220 cc	1100 cc
Atlas A 40 per cent sodium arsenite	50 cc	500 cc	1000 cc
Stantox...(amine salt 2,4-D)	110 cc	220 cc	1100 cc
Ammate (ammonium sulfamate)	22 grams	45 grams	100 grams
Methyl Ester (Baker Chemical Co.)	120 cc	250 cc	500 cc
Cyanamid Dust	1 pound	5 pounds	10 pounds

*O—Untreated plot.
A—Lowest amount of herbicide 10 by 10 plot.
B—Medium amount of herbicide 10 by 10 plot.
C—Largest amount of herbicide 10 by 10 plot.
**N—Normal growth.
I—Plants showed injury.
O—No plants growing.

Under field conditions growth of oats indicates that in soils treated with 2,4–D 30 pounds/acre and more, stand was seriously reduced unless at least 6 weeks time had elapsed between spraying and planting. Ammonium sulfocyanate and Sodium arsenite also reduced stand in oats. With the amounts used their effectiveness was longer lasting than that of 2,4–D salts. Untreated plots gave normal growth of Victory oats in all cases. In other plots and greenhouse tests reduction in stand of oats was limited to a month or to 6 weeks. This was true also of lawn grasses (Kentucky blue grass, fescue and colonial bent). Red Kidney beans and zinnia also germinated but showed abnormalities associated with 2,4–D injury and after 4 months all crops still showed stimulation.

While oats do not constitute a weed they are useful as a test crop. Their response follows that described by Allard (1) and the relation with concentration of 2,4–D applied as a bathing solution is summarized in Table IV.

TABLE IV—Response of Oats After Two Weeks Growth Following Soaking Three Hours in Solutions of 2,4–D Prior to Planting

2,4-D Compound	Threshold Concentration (Ppm) for Injury			
	Root Reduced	Top Curled	Dwarfing	Stimulation
Acid-carbowax	1,000	250	250	25
Amine salt (C)	250	500	250	5
Amyl Ester	500	500	250	1
Morpholine salt	250	1,000	50	1
Methyl Ester	500	500	100	1
Methyl Ester (C)	250	500	250	1
Sodium salt	1,000+	500	100	25

Summary

When 2,4–D is applied at rates equivalent to 5 pounds acid per acre or in solutions of 5000 ppm at 200 gallons to the acre, stands of annual grasses are reduced. Applications of this strength severely injured wild white clover but produced no permanent injury in common lawn grasses. Two sprays of high concentration a year caused no serious injury when spaced at 6 weeks intervals. Repeated spraying at short time intervals offers a possible control of annual grasses which continue to germinate over long periods of time. Spraying can be stopped when the desired degree of control is obtained.

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The Effect of 2,4–D on Root Induction

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

The activity of 2,4–dichlorophenoxyacetic acid on plant growth parallels in many ways the activity of indolebutyric and naphthalene acetic acids as indicated by Hitchcock and Zimmerman (1). The value of these two growth regulators stimulating root production in cuttings is well known. The purpose of the present tests is to determine the activity of 2,4–dichlorophenoxyacetic acid as a root inducing agent. Both untreated cuttings and others treated with indolebutyric acid are used for reference. The data presented are in terms of the performance of the untreated plants rated as 100 and refers to the proportion of the cuttings showing root production. Samples of 25 cuttings were used for each treatment. Four such samples were included in most treatments. Samples were removed from the propagating media at different time intervals. The first interval was purposely selected before any large percentage of the untreated plants were rooted. In these cases the relative rooting associated with the growth regulator may appear exaggerated but helps to establish trends. Data from later intervals show narrower differences but substantiate trends established earlier.

The concentration of growth regulator used was varied in an effort to establish the range over which it was effective for root induction in the test material used. Cuttings were soaked for 24 hours by standing them upright in solutions of growth regulator. Uniform rooting media was employed in each test but varied with the plant material. Coleus, Ilex and Ligustrum were in coarse quartz sand, Taxus in cinders.

Materials and Methods

Coleus Blumei Cuttings Taken in July 1946, Ten Cuttings per Sample:—Each growth regulator had separate untreated sample. Naphthalene acetic acid gave most desirable cuttings with 50 ppm treatment, profuse consistent rooting averaging ½ inch in length, while the untreated group had few roots of ¼ inch average length. Treatment with 200 ppm of acid injured the ends of the cuttings, roots were few and averaged ¼ inch indicating that the upper limit of concentration had been reached.

2,4–D Acid and Salts:—Some rooting occurred and was accompanied by epinasty and yellowing of the foliage. Response indicated 50 ppm is above any possibly useful amount for root induction. 2,4–D in Carbowax at 50 ppm was as well rooted as the untreated group. Morpholine salt and amine salt were least toxic, methyl ester the most, followed by sodium salt.

Ilex Aquifolium and Ilex Hybrid, August 16, 1945:—Response to indolebutyric acid passes through an optimum concentration while amine salt of 2,4–D gave response comparable to indolebutyric stimulation when the 2,4–D was used at 10 ppm. Higher concentrations were injurious. Cuttings failing to root were dead in 2,4–D treatments of 40 ppm and over while this held true only for indolebutyric at 750

TABLE I—COMPARATIVE NUMBER OF CUTTINGS ROOTED WITH REFERENCE TO "UNTREATED" RATING 100

Plant Material	Days in Media	Form of 2,4-D	Concentration of Indolebutyric Acid (Ppm)								Concentration of 2,4-D (Ppm)										
			0	2.5	25	50	100	200	500	750	2.5	10	25	40	50	80	100	160	200	320	500
Coleus Blumei	7	Naphthalene acetic	100	—	—	111	111	111	—	—	—	—	—	—	—	—	—	—	—	—	—
	7	2,4-D Carbowax	100	—	—	—	—	—	—	—	—	—	—	—	100	—	100	—	40	—	—
	7	Sodium salt	100	—	—	—	—	—	—	—	—	—	—	—	30	—	0	—	50	—	—
	7	Morpholine salt	100	—	—	—	—	—	—	—	—	—	—	—	0	—	30	—	100	—	—
	7	Methyl ester	100	—	—	—	—	—	—	—	—	—	—	—	0	—	0	—	0	—	—
	7	Amine salt	100	—	—	—	—	—	—	—	—	—	—	—	50	—	0	—	0	—	—
Ilex aquifolium	60	Amine salt	100	—	—	450	880	800	1,000	533	—	700	—	100	—	30	—	60	—	30	—
Ilex hybrid	60	Amine salt	100	—	—	1,050	950	1,200	900	300	—	950	—	150	—	150	—	100	—	200	—
	90	Amine salt	100	—	—	90	100	70	—	35	—	120	—	70	—	30	—	80	—	50	—
Ligustrum vulgare	60	Amine salt	100	110	96	105	90	94	86	—	94	—	112	—	105	—	80	—	63	—	44
Taxus cuspidata	60	Amine salt	100	—	—	613	—	—	—	—	—	80	68	—	139	—	—	—	—	—	—
	100	Amine salt	100	—	—	240	—	—	—	—	—	140	124	—	152	—	—	—	—	—	—
	90	Amine salt	100	129	158	211	225	232	175	—	208	—	125	—	182	—	124	—	119	—	94
	90	Methyl ester (A)	—	—	—	—	—	—	—	—	60	—	220	—	50	—	100	—	5	—	252
	90	Methyl ester (B)	—	—	—	—	—	—	—	—	87	—	51	—	124	—	76	—	157	—	542
Taxus medial Hicksii	120	Amine salt	100	—	—	300	300	—	—	—	275	213	225	237	—	—	—	263	—	—	—
	120	Vacuum treated	100	—	—	181	119	—	—	—	145	181	145	73	—	—	—	101	—	—	—

ppm. The 90 day observations on the *Ilex hybrid ((chinensis x opaca)* LeMac Nurseries, Hampton, Virginia) indicate an optimum rooting with indolebutyric acid at 100 ppm and that comparable results can be obtained with 2,4–D at 10 ppm.

Ligustrum Vulgare, August 29, 1946:—Four samples of 25 cuttings for each treatment were used and averaged. Rooting response from treatment with indolebutyric does not indicate an optimum concentration while that for 2,4–D does at 25 ppm. In the range of 2.5 ppm to 50 ppm the amine salt of 2,4–D is equal to indolebutyric acid as a root inducing agent. In concentrations above 100 ppm response to both regulators declines.

Taxus Cuspidata, September 12, 1945:—Includes nine replicates for the 60 day group and 17 for the 100 day group for each treatment in each group. Indolebutyric acid proved more effective for rooting induction than did the amine salt of 2,4–D which appears to show a minimum response at 25 ppm. When August 12, 1946 tests are considered the amine salt is again somewhat less effective than indolebutyric acid. Both growth regulators reach optimum response at 200 ppm passing through an optimum at that point. Methyl esters gave variable results and lack any consistent trend except that the optimum point is higher over 200 ppm.

Taxus Media Hicksii October 12, 1945:—After 120 days in the propagating media there is little relation between the concentration of regulator applied and the rooting response both being about a gain of similar magnitude. Unrooted cuttings were still alive with the indole treatments but were dead in 2,4–D treatments.

Forcing the growth regulator into cuttings by immersing the cuttings and creating a vacuum over the bathing solution resulted in considerable loss of air from the leaves and stem ends of the cuttings. At the conclusion of a 5-minute treatment the cutting had a water soaked appearance. The rooting response indicates a maximum with 2,4–D at 10 ppm and definite injury at concentrations over 40 ppm.

Other Growth Regulators:—In a preliminary test with *Taxus Cuspidata* in December 1, 1945 ten growth regulators were compared with indolebutyric. Cuttings remained 150 days in the propagating bed. Four samples of 25 cuttings were used in each test. The growth regulators were applied at 50 ppm. The results are given in Table II.

TABLE II—ROOTING RESPONSE IN *Taxus Cuspidata* WITH GROWTH REGULATORS OF PHENOXYACETIC ACID GROUP (DATA RELATIVE TO UNTREATED CUTTINGS RATED AT 100)

Growth Regulator (50 Ppm)	Rating of Rooting
2,4-Dichlorophenoxyacetic acid	105
2,4,5-Trichlorophenoxyacetic acid	133
p-chlorophenoxyacetic acid	108
o-chlorophenoxyacetic acid	100
p-methylphenoxyacetic acid	122
o-methylphenoxyacetic acid	128
m-methylphenoxyacetic acid	128
3,5 Di Methylphenoxyacetic acid	78
p-nitrophenoxyacetic acid	83
a naphthoxyacetic acid	122
r (indole-3)-n-Butyric acid	135
Fermate (ferric dimethyl dithio carbamate)	108

While the present test is confined to a single concentration of each growth regulator, none appears to be better than indole butyric acid nor are any to be disregarded on the basis of these tests.

SUMMARY

2,4–Dichlorophenoxy acetic acid over the concentration range of 2.5 ppm to 750 ppm shows approximately the same ability for root induction as does indole butyric acid.

The use of 2,4–D for rooting cuttings of herbaceous materials is a practice of doubtful value. The effect of 2,4–D on changing the character of ornamental plants has already been described. Results stated here are considered primarily in terms of the number of cuttings rooted in each sample. Attention has been called to injury where this resulted in high mortality in unrooted cuttings.

No estimate is given of the amount or character of roots produced. These follow the pattern of indole butyric acid. High concentrations that are not lethal change the rooting habit. Numerous stiff short roots spread along and around the stem rather than a few long roots arising from the end of the cutting.

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Comparison of Various Lamp Sources for Increasing Growth of Greenhouse Crops[1]

By Alice P. Withrow and R. B. Withrow, *Purdue University, Lafayette, Ind.*

A great deal of interest has been shown recently in the use of artificial sources of radiation over greenhouse crops for producing more vigorous plant growth during the winter months when cloudy weather and short days are prevalent in the northern United States. The minimum day-length in this region varies from about 9 to 10 hours during the winter, and for extended periods, at this season, the solar irradiance may not go above a few hundred footcandles as compared with a 5000 to 10,000 footcandles maximum prevailing during the summer months. The problem of producing vigorous plant growth, therefore, is one of increasing the irradiance, as well as, in many cases, increasing the photoperiod.

The use of artificial sources of radiant energy for this purpose is economical in commercial plant production in a very limited number of situations, since relatively high irradiances are necessary to secure appreciable growth increases and the cost of installation, power, and lamp replacement frequently approaches or surpasses the value of the crop being treated. The use of high irradiances is economical for increasing the rate of growth of seedlings and young plants which can be closely spaced or for improving growth in special crops. It also is a valuable tool in experimental work.

Procedure

In the present experiment, three lamp sources were compared as to the general growth responses secured with several annual plants. Nobel spinach and Heart of France China aster were seeded January 7, and transplanted to subirrigation gravel beds on January 22; Biloxi soybean and Indiana Baltimore tomato were seeded January 22 directly in the gravel beds. A Purdue F nutrient solution at double concentration was used (3). This type of plant material was selected because of the authors' interest in applying the results secured to photoperiodic studies then in progress. The plants were given normal daylight conditions supplemented from 6:30 p. m. to 12:30 a. m. with energy from incandescent, fluorescent and high pressure mercury arc sources. The supplemental irradiation treatments were begun January 30.

The fluorescent and high pressure mercury arc (H–1) lamps have about the same efficiency in lumens per watt. Since both sources require auxiliaries for operation, the power requirement of these must be added to the nominal lamp wattage to secure the actual power consumption per unit. This means that the actual power consumption of the lamps is increased from 400 to 452 watts for the H–1 mercury arc lamp with a single lamp transformer (1). For each 30 watt, 36 inch daylight fluorescent tube used, the power consumption is increased to

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[1] Journal Paper No. 278, Purdue University Agricultural Experiment Station.

37¼ watts by the tulamp ballasts and the actual consumption for the 16-lamp bank used in the experiment was 596 watts, rather than the 480 nominal wattage. Using the luminous efficiency of the various lamps as a basis for calculation (1), the height of the lamps was so adjusted that the same power per square foot of bench space was consumed. The fluorescent lamp assembly shaded the plants during the day and it had to be removed each morning and be replaced each night.

A control plot was set up, having the same daylength as in the other treatments, but the irradiance employed was 1 footcandle from a 10-watt incandescent lamp. This type of control was used so that the effective photoperiod with regard to flower bud formation would not be a differential factor in the growth of the plants. The temperature was manually controlled at about 70 degrees F during the day and 60 degrees during the night.

The tomato and soybean plants and a portion of the aster plants were harvested on March 1, after 30 days of irradiation. The weight and height data secured at this time are presented in Table I. On May 10, 70 days from the beginning of supplemental irradiation, the spinach and the remainder of the aster plants were harvested. The data on height and weight taken at this time are presented in Table II. The plants from both harvests were dried in a forced draft oven at 110 degrees C for dry weight data. Photographs of aster and spinach taken at the time of the later harvest are shown in Fig. 1.

TABLE I—RESPONSE OF CERTAIN GREENHOUSE GROWN CROPS TO SEVERAL SOURCES OF SUPPLEMENTARY RADIANT ENERGY 30 DAYS AFTER TREATMENTS WERE BEGUN

Source*	Irradiance Maximum (Footcandles)	Plant Material**														
		Indiana Baltimore Tomato					Heart of France China Aster					Biloxi Soybean				
		Average Height (Cms)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)	Dry Matter (Per Cent)	Top-Root Ratio	Average Height (Cms)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)	Dry Matter (Per Cent)	Top-Root Ratio	Average Height (Cms)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)	Dry Matter (Per Cent)	Top-Root Ratio
Incandescent 500 watts	210	6.0	6.5	0.44	6.8	6.5	6.0	4.5	0.44	9.4	6.2	25.0	8.2	1.09	13.2	9.3
Fluorescent 480 watts†	360	5.4	6.4	0.45	7.2	4.6	5.4	4.4	0.41	9.1	6.7	20.0	6.9	0.85	12.4	7.7
Mercury 400 watts†	360	3.7	7.2	0.47	6.6	6.2	3.7	4.7	0.41	9.1	6.3	20.8	7.6	0.96	12.6	9.5
Incandescent 10 watts	1	2.5	2.1	0.16	7.8	4.1	2.5	2.0	0.21	10.1	6.0	18.2	4.7	0.53	11.4	7.6

*On 6 hours daily from 6:30 p.m. to 12:30 a.m.
**34 plants per treatment.
†Nominal wattage.

DISCUSSION OF RESULTS

After the 30 days irradiation, all of the plants grown with the high irradiances were decidedly taller and heavier than those grown with 1

TABLE II—RESPONSE OF SPINACH AND CHINA ASTER TO SEVERAL SOURCES OF SUPPLEMENTARY RADIANT ENERGY 70 DAYS AFTER TREATMENTS WERE BEGUN

Source*	Irradiance Maximum Foot-candles	Plant Material**									
		Nobel Spinach					Heart of France China Aster				
		Average Height (Mms)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)	Dry Matter (Per Cent)	Top-Root Ratio	Average Height (Cms)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)	Dry Matter (Per Cent)	Top-Root Ratio
Incandescent 500 watts	210	5.2	18.7	1.39	7.4	14.4	46.9	74.9	8.06	10.7	9.6
Fluorescent 480 watts†	360	52.3	27.9	1.78	6.3	21.5	21.4	49.2	4.81	9.7	6.6
Mercury 400 watts†	360	14.7	8.6	0.62	7.2	25.0	18.6	35.8	3.84	10.7	7.7

*On 6 hours daily from 6:30 p.m. to 12:30 a.m.
**20 plants of spinach per treatment; 12 plants of China aster per treatment.
†Nominal wattage.

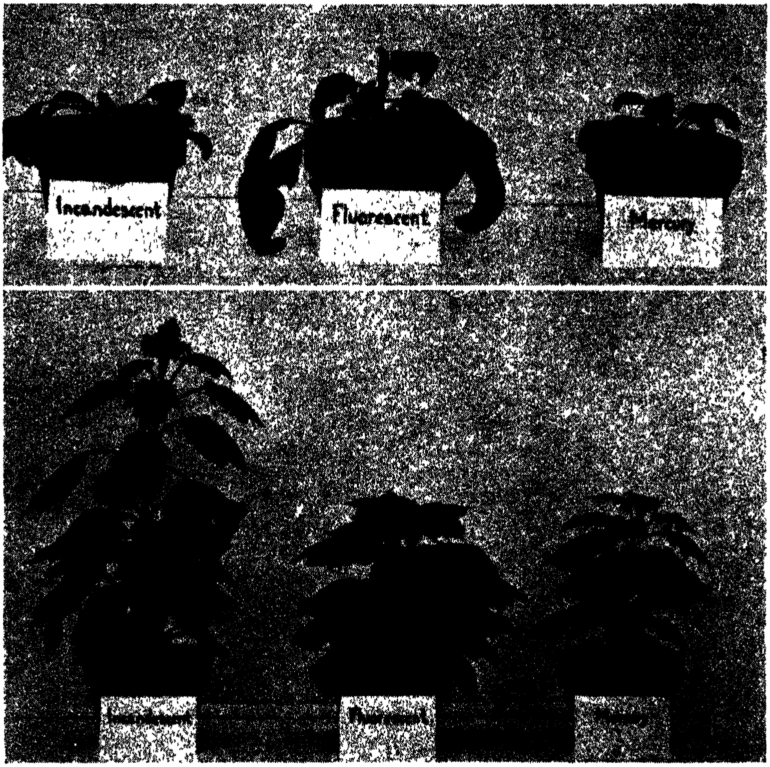

FIG. 1. Response of Nobel Spinach and Heart of France China aster to supplemental high intensity greenhouse lighting.

footcandle incandescent radiant energy. This indicates that irradiances in the range of the higher values used are effective in bringing about appreciable increases in height and dry weight at this time of the year. However, the differences in weight between plants under the various sources were slight and no consistent trend was noticeable. The greatest per cent dry matter occurred under the incandescent source for aster and soybean, while the tomato had the greatest per cent under the low irradiance incandescent. As to top-root ratio, great variability also occurred here, although, in general, the plants under the fluorescent had the smallest top in proportion to root size. The only consistent trend was in height; the plants under the high irradiance incandescent were tallest at this early harvest.

Seventy days from the beginning of the radiation treatments, the spinach plants were largest, and the flowering spike longest under the fluorescent. On the other hand, the aster plants were tallest and heaviest under the incandescent. The smallest plants occurred under the mercury. The per cent dry matter and top-root ratio data show no consistent trend of differences. The photographs in Fig. 1 show the general type of growth secured under the various sources.

For all the crops except spinach, that is the warm temperature crops, the incandescent source gave as good or better general growth responses than the fluorescent or mercury sources. The shade factor introduced by the bulky reflector and auxiliaries of the fluorescent luminaire made this source of questionable value for greenhouse use, especially since the general growth was not much different from that secured with the cheaper and more easily handled incandescent source. The mercury also requires a reflector and auxiliary equipment which present, to a lesser degree, the same disadvantage as the fluorescent lamp assembly.

Subsequent work with high wattage 300-watt internal reflector flood lamps (2) indicates that this type of lamp is an excellent incandescent source. No reflector is necessary. However, care should be taken to keep the lamps 24 to 30 inches from the tops of the plants to prevent burning of the foliage. Porcelain sockets should be installed, since these lamps become very hot. If the indoor internal reflector lamps are used, water dropping on the lamps, either from the greenhouse roof or other sources when the lamps are hot, causes them to break. Outdoor type lamps in pyrex can be purchased in lower wattages.

In any lighting installation of this type, care should be taken in the spacing of the lamp mountings, so that wide fluctuations in irradiance do not occur across the bench or bed nor down the length of the bench. Usually two lengthwise rows of lamps are preferable to one row in securing even irradiance conditions over a bench wider than 3 feet.

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Effect of the Methyl Ester of a-Napthaleneacetic Acid on the Storage Life of Cauliflower[1]

By R. L. CAROLUS, S. H. LEE, and J. S. VANDEMARK,
Michigan State College, East Lansing, Mich.

WITH the object of finding a means of extending the marketing period of Michigan cauliflower through November or longer, experiments were started in October of 1946 to study the relation of various practices and materials on short and long period storage. The results obtained with the methyl ester of a-naphthaleneacetic acid (NA) have been of such a nature as to warrant a brief report on a possible new use for this so-called "sprout inhibitior" chemical in maintaining the storage life of the crop.

PROCEDURE AND RESULTS

Test I:—Muck-grown cauliflower harvested October 15, 1946, was placed in storage at 32± 2 degrees F and at 60± 5 degrees F. Without trimming the leaves, each head was placed in a 16-pound kraft paper sack. Ten grams of shredded paper impregnated with 50 mgs of NA were scattered loosely on top of and around the heads in 10 bags held at each temperature. An equal number of untreated heads was available for comparison.

The following observations were made on December 15. Heads stored at 32 degrees F that were untreated with NA were badly shriveled, and all but a few of the smaller innermost leaves surrounding the curd had abscissed, yellowed, and partially dried. Heads treated with NA and held at the same storage temperature were marketable, the leaves being green and showing no tendency to absciss, although some wilting had occurred.

On the other hand, heads stored at 60 degrees F were all unmarketable due to a considerable amount of foliage and some curd decay. The treatment with NA at this temperature resulted in a breaking up of the curds due to growth and an elongation of individual florets of as much as 3 inches. Untreated heads held at this temperature showed no growth and no breaking up of the curd. Any differences that there may have been in the amount of abscission were obscured by the decay.

The observations in this test indicate that the chemical behaved differently at different temperatures. When the temperature was sufficiently high for growth, it promoted the elongation of the inflorescence, whereas at a temperature too low for growth, the development of an abscission layer was greatly retarded.

Test II:—Arizona cauliflower purchased on the local wholesale market was used in a test initiated January 16, 1947. The heads were stored in bags at 32 degrees F and treated (6 per treatment) as follows: (A) 200 mgs per head of NA impregnated in shredded paper; (B) check (untreated); (C) 100 mgs of NA in shredded paper; (D) 50 mgs NA in shredded paper; and (E) 100 mgs NA sprayed on the leaves and cut stem. Typical results from three treatments after 30 days storage are shown by representative heads in Fig. 1, and are in agreement with the observations of the initial test. Abscission of leaves was observed in 32 days with untreated heads, in 80 days with those treated with 50 mgs of NA, and in 92 days with those treated with 200 mgs of NA. Heads sprayed with 100 mgs of NA showed a slight but unobjectionable burning of the edges of the leaves, (Fig. 1), indicated by shrivelling of leaf blade edges and slight darkening of midrib tissues. Loss in weight was associated with the development of an abscission layer. In 80 days the untreated heads showed an average loss in weight of 31 per cent; the 50 mg-treatment, 24 per cent; and the 200 mg-treatment, only 20 per cent. The relative humidity of the storage was approximately 85 per cent.

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[1] Journal Article No. 901 (n.s.) of the Michigan Agricultural Experiment Station.

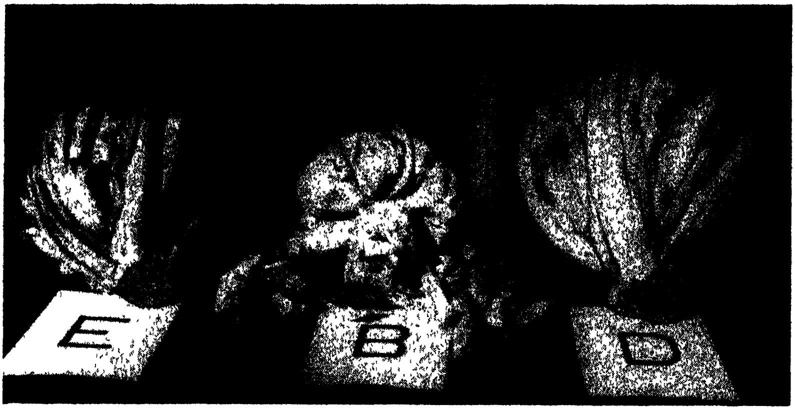

FIG. 1. Effect of NA on abscission of cauliflower leaves. (E) 100 mgs sprayed on foliage, (B) untreated, (D) 50 mgs in shredded paper stored with the head.

Test III:—Cauliflower was shipped from Texas, requiring 4 days to reach East Lansing. Part of the shipment had been placed in bags containing 100 mgs of NA in shredded paper at the time of harvest, February 16,[2] and part left untreated. Both lots were again stored at 32 degrees F. Observations made on arrival and before placing in storage showed no appreciable differences in appearance between treated and untreated heads. In 60 days of storage untreated heads lost 24 per cent in weight and treated heads lost 18 per cent. Abscission of leaves was observed in 45 days in the untreated heads, but did not occur until 103 days with treatment. The effect of NA on the development of the abscission layer photographed 25 days after treatment is shown in Fig. 2.

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[2] Heads were collected and treated by S. B. Apple, Extension Horticulturist, Edcouch, Texas.

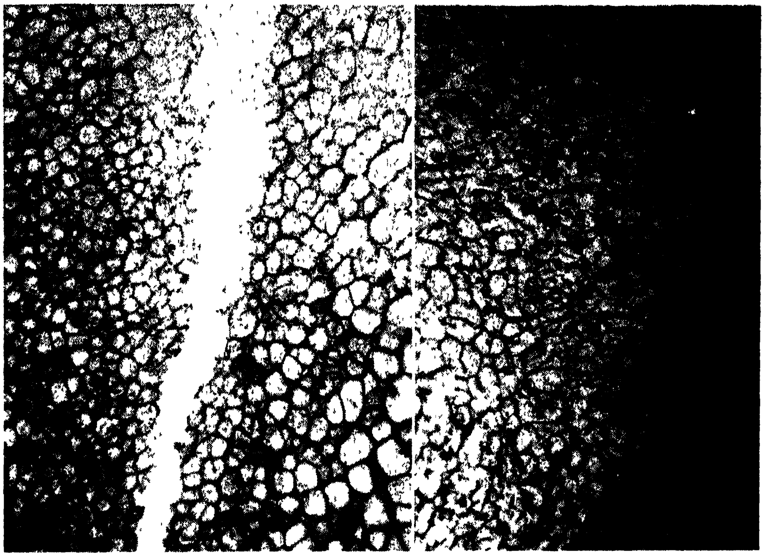

FIG. 2. Longitudinal section through region of abscission of petioles of cauliflower leaves. ×125. Left, untreated; Right, treated with NA.

CONCLUSIONS

Under conditions of low temperature (32± 2 degrees F) and a relatively low humidity (80 to 90 per cent), the development of an abscission layer in the leaves of stored cauliflower is markedly retarded by treatment with the methyl ester of a-naphthaleneacetic acid. At higher temperatures (60 degrees F) the curd is broken up and individual florets may elongate as much as 3 inches in 60 days. The elongation of the inflorescence at higher temperatures by NA treatment may be of value in the production of vegetable seed. Experiments now under way indicate that the same effects, but to a lesser degree, may be expected with stored cabbage.

2,4–D Treatment for the Control of Weeds[1] in Plantings of Gladioli

By PAUL R. KRONE and CHARLES L. HAMNER, *Michigan State College, East Lansing, Mich.*

IN previous publications (1, 2) the possibility of controlling weeds by applying 2,4–D to soil 3 to 6 weeks prior to sowing seeds of economic crops has been presented. The fact that some plants are less subject to injury by 2,4–D than others suggests that such treatments may be found especially suited to certain crops. Gladioli (*Gladiolus spp.*) are among those plants which seem to be relatively resistant to 2,4–D. This paper deals with the possibility of controlling weeds in fields of gladioli.[2]

PROCEDURE — SOIL TREATMENT

To determine whether 2,4–D could be used on gladiolus soils to control weed growth and still not injure gladiolus plants, various amounts of the sodium salt of 2,4–D were applied to different soil types at varying times. In addition to the planting at Michigan State College, the experiments were repeated in the fields of commercial gladiolus growers at Ann Arbor, Monroe, and New Baltimore, Michigan.[3] The soils treated included muck, a sandy loam, and a rather heavy clay loam.

The first treatment was applied to the muck soil at East Lansing on April 27, 1946. These plots served as a guide in determining the rate and method of application on the other plots. The 2,4–D was applied at Monroe on June 8, at New Baltimore on May 19, and at Ann Arbor on June 10.

A 70 per cent preparation of the sodium salt of 2,4–D was used in all the soil treatments. It was dissolved in water and applied with a knapsack sprayer to the mineral soil plots at the rate of 2, 5, 10, and 20 pounds per acre. In addition, two plots on the muck were treated with 50 pounds per acre.

The sprayer was equipped with a special nozzle which produced a fan-type spray. A more rapid and even distribution of the chemical was obtained with this fan-type nozzle than with one delivering a spray in the form of a cone. On the plots at New Baltimore and Ann Arbor, the 2,4–D was mixed with talc and sand and spread dry.

The weather during the spring was both cool and dry from April until June. The summer was extremely dry with less than an inch of rain falling between June and September in East Lansing. The plots were not irrigated.

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[1] Journal Article No. 851 (n.s.) of the Michigan Agricultural Experiment Station.

[2] This investigation was supported in part by a grant from the Dow Chemical Co. of Midland, Michigan who also supplied the chemicals used.

[3] Appreciation is extended to Mr. Russell Everhart, Ann Arbor, Mich., Mr. C. E. Sheely, Monroe, Mich., and to Mr. Nick Koenig of New Baltimore, Mich., for their cooperation in this project.

EXPERIMENTS AT EAST LANSING

The muck plantings at East Lansing were divided into 15 plots. Five plots were set up in duplicate in one section. They were sprayed with 2,4–D on April 27 at the rate of 1, 2, 5, 10, and 50 pounds of the chemical to the acre. One hundred and fifty size No. 6 gladiolus corms and 1 pound of cormels were planted in each of the plots at intervals of 2, 3, 4, and 5 weeks after the 2,4–D was applied. The size of each plot was 20 by 50 feet and the corms or cormels were planted across each plot so that each row in a treatment was 20 feet long.

Five other plots were then arranged on which the corms were planted on May 6 and 2,4–D applied at the rate of 2, 5, 10, and 20 pounds per acre immediately following planting.

All treatments except that at 50 pounds per acre were repeated at Ann Arbor on a heavy clay soil, at Monroe on a steady loam soil, and at New Baltimore on a heavy clay loam soil.

In another experiment at East Lansing, No. 1, 2, 3, 4, 5, and 6 corms and cormels were planted on June 4 in a sandy loam plot ¼ acre in size. The soil had not been fertilized during the past 3 years and corn had been grown on it in 1945. In order to find out what effect 2,4–D would have on the yield of corms, five rows were selected and 600 No. 6 corms of mixed varieties were weighed and planted in each treatment. At the time of harvest the corms and cormels in each lot were again weighed and the increase in weight determined.

After the corms were planted, one-third of the plot was treated with 2,4–D at the rate of 10 pounds per acre and one-third at 20 pounds per acre. The remainder of the plot was left untreated as a check. The rows ran crosswise to the treatments.

PROCEDURE — SPRAY TREATMENT

Part of the untreated plants in sand used in the soil treatment experiment at East Lansing were sprayed during the summer to determine the effectiveness of certain spray materials used for weed control on other crops and to compare any possible injury resulting from these materials to any that might be caused by the 2,4–D soil treatment. The fifth row was left unsprayed as a check on both the spray treatments and the soil treatments.

Stanisol, Dow Selective Weed Killer,[4] sulphuric acid and 2,4–D were the materials used. The Stanisol was not diluted. The Dow Selective Weed Killer was used at the rate of 16 cubic centimeters per gallon of water. Sulphuric acid was used as a 2 per cent solution and 2,4–D at a concentration of 1 to 1000. Each plot was sprayed three times. The soluble salt form of 2,4–D was used for the first and third applications, and 2,4–D in the emulsion form was used on the second.

RESULTS — SOIL TREATMENT

Weed Control:—Over 90 per cent of the weeds were destroyed where 2,4–D was applied at the rate of 5 pounds or more per acre on all plots except on the muck and on commercial plantings at New Baltimore.

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[4] The ammonium salt of dinitro secondary butyl phenol.

Where 2,4–D was applied at the rate of 10 and 20 pounds per acre on sandy loam soil at East Lansing, over 95 per cent of the weeds were destroyed. A few weeds survived the treatment of 10 pounds per acre. They were: ground cherry *(Physalis* sp.), bromegrass *(Bromus seculinas)*, and milkweed *(Asclepias syrica)*.

The soil treated at 20 pounds per acre was free of weeds except for an occasional plant of ground cherry and milkweed. The untreated plot was heavily infested with weeds including lambs quarters *(Chenopodium album)*, pigweed *(Amaranthus riboflexus* L.), bindweed *(Convolvulus arvensis)*, ground cherry *(Physalis* spp.), ragweed *(Ambrosia elatior)*, milkweed *(Asclepias syriaca)*, and bromegrass *(Bromus seculinus)*.

Failure to obtain a kill of weed seed with 2,4–D at New Baltimore was attributed to an extremely heavy rain storm immediately following the application of 2,4–D in talc dust, for there was a considerable slope to the ground, and the materials undoubtedly washed away.

Control of weeds on the muck soil with 2,4–D was not as effective as on mineral upland soils. Early in the season control of approximately 80 per cent was obtained, but by July 1, no differences could be observed in the amount of weed growth either in any of the 2,4–D plots or when compared to the untreated plots. This was in sharp contrast to the results obtained on mineral soils in which over 90 per cent control was obtained on all applications over 5 pounds per acre as shown in Fig. 1. Moreover, the control of weed growth lasted throughout the summer.

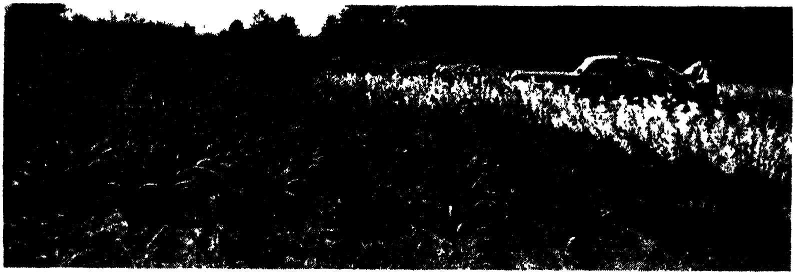

FIG. 1. Gladioli planted 4 weeks after 2,4–D treatment to the soil. Two rows in each treatment (left to right) received 2, 5, 10 and 20 pounds of 2,4–D per acre respectively. There was no apparent difference between treatments. Gladioli blooming at right and in background were planted 4 weeks earlier.

Control of weeds with 2,4–D at both Ann Arbor and Monroe was very good. Over 95 per cent reduction in weed population was obtained on all treatments with 2,4–D at 5 pounds or more per acre. At Monroe over 90 per cent of the weeds were controlled with 2 pounds of 2,4–D per acre. The plots at Monroe on sandy soil treated with 2,4–D consistently showed better control of weeds throughout the summer than was obtained at any other site.

Corm Development:—The main objective in measuring corm growth was to see if any injury or inhibition occurred as a result of the treatment. The data presented in Table I show that the increase in weight of the corms in all plots treated with 2,4–D at East Lansing was greater than it was in the untreated plots, even when the material was applied after planting; and that in three of the five plots the increase in weight of the corms was greater in the plot which received 20 pounds per acre than it was in the one receiving 10 pounds per acre.

The data obtained from these plots, then, would seem to indicate that treatment of the soil with 2,4–D at the rate of 10 to 20 pounds per acre after planting was not injurious to gladiolus corms. If any injury had occurred, it would seem that it would have been greater at 20 pounds per acre than at 10 pounds per acre.

The results at Monroe and Ann Arbor, however, did not substantiate this belief. Careful observations there indicate that when the 2,4–D was applied after planting, the total weight of the corms dug and the percentage of No. 1 corms dug was materially reduced.

In contrast to this however, the production in the plots which were planted 3 weeks after treatment was greater than in the untreated plots, and at Monroe when all plantings of each treatment were combined there was a definite increase both in weight dug and in the number of No. 1 corms in those plots receiving 10 and 20 pounds of 2,4–D as compared to those receiving 2 pounds per acre. Eighty-five No. 1 corms were dug in the 2-pound plot, 134 in the 5-pound plot, 173 in the 10-pound plot and 190 in the plot receiving 20 pounds of 2,4–D per acre. The total weights dug ranged from 18.4 kilograms in the 2-pound plot, to 20.6 kilograms in the 5-pound plot, 21.3 in the 10-pound plot, and 21.03 in the 20-pound plot.

Although somewhat variable results were obtained on the muck plantings, the increase in weight where No. 6 corms were used was considerably greater in the treated plots than in the untreated ones. The corms in the plot receiving 2 pounds per acre increased 318 per cent in weight. Those in the plots receiving 5 pounds per acre increased 215 per cent and those in the plots receiving 20 pounds per acre increased 186 per cent, as compared to an increase of 109 per cent in the untreated plots. An inconsistency occurred in the plot receiving 10 pounds per acre, where an increase of only 79 per cent was obtained. Small bulblets grown in muck showed a fairly consistent decrease in the amount of weight gained, ranging from a 264 per cent increase in the untreated plot to a 76 per cent gain in the plot receiving 20 pounds per acre. The bulblets were planted very shallow and may have been injured by the 2,4–D.

Abnormally poor yields in all plots planted at intervals of 2, 3, 4, and 5 weeks after treatment with 2,4–D were attributed to the extremely dry weather. The growth in all of these plots including the untreated ones became progressively poorer as the season advanced and the muck dried out more severely. Consequently the results were not considered to be worthy of consideration.

General observations during the summer indicated that there was some retardation in growth on the gladiolus tops during the early season. On the sandy loam at East Lansing growth retardation was observed on the plots receiving 10 and 20 pounds per acre. Differences in growth appeared less pronounced as the season progressed and at time of harvest no differences between the treated and untreated plants were noted.

RESULTS AT ANN ARBOR

The same type of retardation was observed at Ann Arbor where the application was made on June 10 except that here it was considerably more pronounced. Observations made on August 22 revealed a gradual decrease in the height of the plants from a high of 14 to 18 inches in the untreated plots of No. 6 corms to 8 to 10½ inches on the plot receiving 10 pounds per acre, and 6 to 8 inches on the plots receiving 20 pounds per acre. The cormels seemed to be affected even more seriously. Those on the untreated plot were 10 to 12 inches high, while on the plot receiving 20 pounds per acre they were only 3 to 6 inches high.

Where the corms were planted 17 days after treatment (June 27) there was very little difference between the untreated and the treated plots. There was no apparent difference between the plots which were planted 3 weeks after treatment. The plants in all of these plots were 10 to 12 inches high and no other differences could be discerned. The plants in the plots receiving 10 pounds and 20 pounds per acre respectively which were planted 4 weeks after treatment were considerably better than those in the untreated plot. There was excellent weed control on the treated plots while a heavy stand of weeds appeared on the untreated plots.

RESULTS AT MONROE

The plots at Monroe were probably the best in the series. Size No. 4 corms were used which provided an opportunity to study any effect upon flowering. In the plots which were treated after planting there was a definite retardation in growth during the early season. This retardation which was evident up to and through the blooming season varied directly with the date of application of the 2,4–D.

On August 22, the plants in the untreated plot and in the one receiving 2 pounds per acre were just starting to come into full bloom. Several spikes were starting to open on the plot treated with 5 pounds per acre but only a few showed any color on the 10-pound plot and only one spike showed color on the plot which received 20 pounds per acre.

On September 19 the plants in the plots which had been treated with 2 and with 5 pounds of 2,4–D per acre were nearly through flowering. Those in the plot which had received 10 pounds per acre were coming into full bloom and those in the plot receiving 20 pounds per acre were just coming into bloom as shown in Fig. 2.

There was a corresponding retardation, although to a lesser degree, on those plots planted 2 weeks after treatment. The retardation on

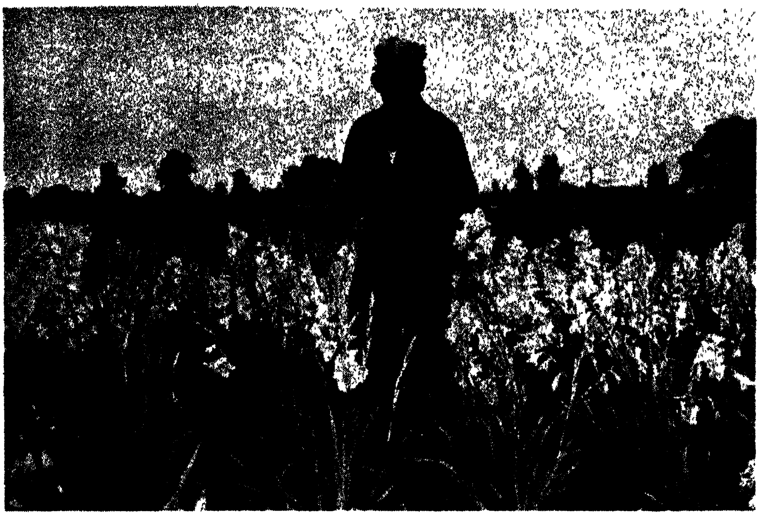

FIG. 2. The two rows of gladioli on the left received 20 pounds of 2,4–D per acre and show delay (approximately 10 days) in blooming as compared with 10 pounds of 2,4–D per acre applied to the two rows at the right of the center.

those planted 3 weeks after treatment was hardly noticeable, while no difference was apparent on the ones planted 4 weeks after treatment (Fig. 3).

FIG. 3. A section of gladioli planting on sandy loam at East Lansing showing control of weed growth with 10 pounds of 2,4–D per acre.

RESULTS — SPRAY TREATMENT

Of the sprays used, the 2,4–D was most effective from the standpoint of weed control. Although there seemed to be little noticeable injury to the gladiolus plants when the material was applied during the very early stage of growth (until the plants were 8 to 10 inches high), they were very noticeably injured later. This injury was also observed on other tests in other plantings. It seemed to be less pronounced on cormels and small corms than on plots grown from larger corms. The injury was definitely greater later in the season. Injury to the plants seemed also to be much more severe when the emulsion form was used than when the soluble salt form was applied.

Table I indicates, however, that injury to the corms was just slightly greater than that caused by sulphuric acid which produced the least injury of any of the sprays. Dow Selective Weed Killer[5] caused some burning of the foliage and a considerable decrease in the weight of the corms dug at East Lansing. Stanisol caused very severe injury, killing most of the plants outright. It was discovered that if the spray was directed at the base of the plant and if it did not hit the tips, the injury from Dow Selective Weed Killer was materially reduced. This practice was followed at Monroe and the concentration was reduced to 13 cubic centimeters per gallon. There seemed to be no injury to the foliage from this application and no decrease in corm production.

TABLE I—THE EFFECT OF 2,4–D SOIL TREATMENT AND OF CERTAIN HERBICIDAL SPRAYS ON THE GROWTH OF GLADIOLUS CORMS PLANTED IN SANDY LOAM SOIL AT EAST LANSING (SIX HUNDRED NO. 6 CORMS WERE PLANTED IN EACH TREATMENT ON JUNE 4)

Plot No	Soil Treatments		Spray Treatments	
	10 pounds 2,4-D Per Acre	20 pounds 2,4-D Per Acre		
	Increase in Weight of Corms (Per Cent)	Increase in Weight of Corms (Per Cent)	Treatment	Increase in Weight of Corms (Per Cent)
1	76.4	49.2	2,4-D Spray	− 6.8
2	138.6	44.4	Dow Selective	−51.8
3	44.4	71.7	Stanisol	−88
4	47.8	172.8	H_2SO_4	− 6.6
5	76.4	126.8	Untreated	−19.7
Untreated	−19.7	−19.7	———	———

DISCUSSION

Results with one summer's work on the use of 2,4–D seem to indicate that 2,4–D can be used on certain types of soil, mainly mineral soils and especially sandy soils, to obtain control of weeds in gladiolus plantings. Whether it is safe to apply the material after the gladioli have been planted is still uncertain. In all cases where this practice was followed there was a definite retardation in the growth of the plants during the early part of the season. 2,4–D not only retards the growth of the tops of the gladioli, but it also delays the time of blooming by about 2 weeks when the soil is treated with 2,4–D at the rate of 10 to 20 pounds per acre immediately after planting.

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[5] The ammonium salt of dinitro secondary butyl phenol.

Although corms grown on treated soil have not been carried through a storage period and grown for a second year, they seem normal and then development has seemed normal. Corm production on the treated plots at East Lansing was as good as, or better than, that on untreated plots. This was also true at Monroe when the 2,4–D was applied at least 3 weeks before planting.

Gladiolus corms planted 3 weeks after treatment of the soil with 2,4–D showed very little, if any, effect of the chemical even when 20 pounds are applied to the acre.

In considering the data in Table I showing the growth of corms at East Lansing, the fact that less than an inch of rain fell after planting on June 4 until September 1 should be emphasized. In addition, this plot was located on very high and normally dry sandy soil. No fertilizer had been used on the soil during the past two years. A crop of corn was grown on it in 1945. These factors may account for the fact that greater increase in weight was not obtained on all plots. They probably account for the variation between individual plots which received the same treatment. The heavy growth of weeds on the untreated plots took a great deal of moisture from the soil and this was undoubtedly responsible for the low increase in weight of the corms on these plots.

One fact should be emphasized, however, and that is that gladiolus corms planted in sandy soil treated with 2,4–D were grown throughout the summer without any weeding or cultivation and still, considering the dry summer, produced a fair yield.

Treatments of gladiolus plantings with various herbicides to destroy weeds after the plants have become established is of questionable value. In all of the treatments any spray except the Dow Selective Weed Killer as it was used at Monroe, that provided weed control also was injurious to the gladioli. It is possible that this material or some other spray material might be satisfactory if a method can be devised for applying it so that it does not strike the gladiolus plants. Any spray to be effective, however, must be applied when the weeds are very small. The sodium salt of 2,4–D may offer some possibilities in the spraying of small plants of small stock. It is definitely injurious, however, to older plants of larger corms.

SUMMARY

Various amounts of 2,4–D were applied to different soils to determine whether it could be used on soils for weed control in gladiolus plantings.

Over 90 per cent of the weeds were killed in sand and sandy loam soils which were treated with 5 pounds or more of 2,4–D per acre.

Some retardation occurred in the top growth of gladioli when the corms were planted immediately prior to treatment of the soil with 10 and 20 pounds of 2,4–D to the acre.

No apparent effect was noted on gladioli planted in soil 3 weeks after it was treated with 2,4–D at the rate of 2, 5, 10, or 20 pounds per acre.

Various other herbicidal sprays were applied to weed foliage in gladiolus plantings. None of the treatments tried at East Lansing gave satisfactory control without some injury to the gladioli. When applied at Monroe at the rate of 13 cubic centimeters per gallon in such a way that it did not strike the tips of the foliage, Dow Selective Weed Killer looked promising.

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The Utilization of Induced Polyploidy in Easter Lily Breeding

By S. L. EMSWELLER, *Bureau of Plant Industry Station, Beltsville, Md.*

THE production of tetraploid floricultural and ornamental plants by means of colchicine is a promising field for the flower breeder. As a rule, doubling the chromosome number of a diploid plant results in larger flowers, thicker petals, and generally increased vigor. However, if the plant is already a polyploid, as are most of our chrysanthemums and dahlias, the results are likely to be disappointing.

So far practically all the floricultural plants made tetraploid by colchicine have been sexually propagated types. As was to be expected, a high degree of sterility and difficulty in fixing varieties were encountered. These impediments are obviated if the new tetraploid can be propagated asexually. Sterility may be an asset, since flowers on such plants usually remain in good condition much longer than those on fertile plants, especially if the latter become pollinated.

The Easter lily, *Lilium longiflorum* Thunb., was used in the present investigations because of its many advantages. It may be propagated easily and very rapidly by scaling the bulbs (3), it does not come true from seed, and larger flowers with improved substance have considerable commercial value. In an earlier paper (1) a description was given of the tetraploid and the diploid of the Creole clone of *L. longiflorum.* In this paper additional tetraploid clones are described as well as several aneuploids and chimeras resulting from colchicine treatments. Some cytological observations are also presented.

MATERIALS AND METHODS

Tetraploids have been secured of Creole, Ace, Estate, and Croft varieties of *Lilium longiflorum.* In addition Beltsville seedling clones 10, 13, 29, 38, 66, 68, 70, 71, and 209 have all been made tetraploid. All these clones propagate readily by forming from one to four adventitious buds at the base of detached bulb scales. At first freshly detached scales were immersed in 1.00, 0.50, 0.25, 0.10, and 0.05 per cent concentrations of colchicine. In the 0.05 per cent concentration the period of immersion was 24 hours. All other treatments were for 1, 2, and 3 hours. Since tetraploids were secured from all treatments, later exposures were all in 0.20 per cent colchicine for 2 to 3 hours.

The scales of the diploid Creole clone were treated in late July and immediately after removal from the colchicine they were planted in sand in flats. In late September the scales and attached bulblets were transferred to soil in a greenhouse bench where they were grown until the following May, when all plants were transplanted to the field. About 500 bulbs selected for further observation were removed from the field in mid-September, potted, and placed in a greenhouse. These did not represent a random sample of the population since only large bulbs with a heavy root system were selected.

RESULTS

The first noticeable effect of the colchicine was the retardation of bulblet formation on the treated scales. Untreated scales usually had small bulblets forming within 10 days, whereas treated ones did not develop any for 4 to 5 weeks. Considerable variation occurred also in width, length, thickness, and roughness of the surface of leaves produced from treated scales.

The chromosome number of 303 plants in the population was determined. The results are shown in Table I. There were 135 diploids, 123 tetraploids, 8 aneuploids, and 37 chimeras. The aneuploids were classified as follows: 1 with 45 (4n — 3) chromosomes; 1 with 46 (4n — 2); 5 with 47 (4n — 1); and 1 with 49 (4n + 1). The chimeras were of 7 types as shown in the footnote of Table I.

TABLE I—POLYPLOIDS PRODUCED BY IMMERSING DETACHED SCALES OF *Lilium longiflorum* IN AQUEOUS COLCHICINE

No. Plants Counted	Diploids (24 Chromosomes)	Tetraploids (48 Chromosomes)	Aneuploids Chromosome Nos.				Types of Chimeras*						
			45	46	47	49	a	b	c	d	e	f	g
303	135	123	1	1	5	1	3	1	1	1	4	2	25
			8				37						

*a. Mixoploid leaves, stomata, pollen, and flowers; tetraploid roots.
b. Octoploid flowers and pollen, tetraploid roots and stomata (stomata widely spaced).
c Diploid roots and stomata; tetraploid pollen and flowers.
d. Diploid roots, flowers, and pollen; tetraploid stomata.
e. Tetraploid roots and stomata; diploid pollen and flowers.
f. Tetraploid roots; diploid pollen, flowers, and stomata.
g. Tetraploid roots, flowers and pollen; diploid stomata.

DESCRIPTIONS OF THE VARIOUS POLYPLOIDS PRODUCED

Each tetraploid and aneuploid has certain characteristics that differentiate it from the parent diploid. They all have broader, thicker leaves, heavier stems, and larger flowers with thicker petals. The increase in flower size, however, is not the same for all clones.

The first tetraploid Easter lily to flower at the Plant Industry Station, Beltsville, Maryland, was the Creole. The number of flowers produced per plant was significantly less than on Creole diploids from comparable-sized bulbs, but the tetraploid flowers were larger, averaging 6.96 ± 0.04 inches in length in comparison with 5.92 ± 0.04 inches for the diploids. The over-all differences between the 2n and the 4n Creole were not sufficient to warrant optimism regarding the value of tetraploidy in the Easter lily.

The Creole aneuploids produced by the treatments were especially interesting. One of the most attractive Easter lily flowers so far seen at Beltsville was produced on the 4n — 3 plant. The perianth segments were broader and curved back more than on any other flower. The other aneuploids, including the 4n — 2, 4n — 1, and 4n + 1 plants, were indistinguishable from the tetraploids except for shorter and broader leaves on the 4n — 2.

None of the chimeras except type b had flowers as large as the tetraploids. The flowers of the four plants of type e appeared star-shaped when viewed face on. The one plant of type b produced a flower slightly over 8 inches long, but it was unable to open more than about 1½ inches, and therefore had no commercial value. The petals were about twice as thick as the tetraploids. This flower was almost certainly octoploid.

Tetraploids of seedling clones 29, 38, 66, and 209 have produced plants and flowers of outstanding quality. The tetraploid of clone 29 produced plants slightly over 8 feet tall, one bearing 28 flowers while the diploid growing at the same time under comparable conditions was slightly over 4 feet tall with no plants bearing more than 10 flowers. When these same bulbs were given preplanting cold storage treatment the tetraploid plants averaged between 4 and 5 feet tall, the diploids between 3 and 4 feet. The flowers of the tetraploid were about 8 inches long and 6½ inches across the trumpet; those of the diploid about 6 and 5 inches for the same dimensions. A diploid and a tetraploid flower of clone 29 are shown in Fig. 1.

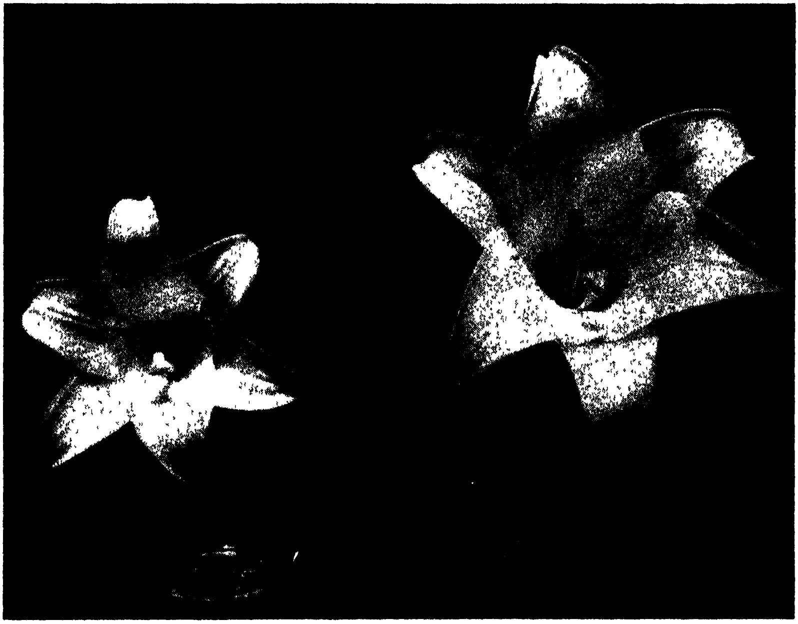

FIG. 1. Flowers of Easter lily *(Lilium longiflorum)* clone 29. Left, diploid; right, tetraploid.

The diploid of clone 38 is low-growing, rarely reaching a height of 24 inches, with very soft flowers. It was destined to be discarded. Tetraploid 38 also flowers on a 24-inch stem, and 9-inch bulbs have produced 8 to 10 flowers. Its flowers are about one-third larger than the diploid; but of greater importance is their considerably increased substance. It is a fine pot type Easter lily greatly admired by all florists who have seen it.

Diploid clone 66 is the most floriferous Easter lily we have seen, 7-inch bulbs producing well over 10 flowers that are rather small and somewhat soft. Tetraploid 66 is a magnificent plant with large, heavy flowers.

The largest flowers so far seen in our Easter lily populations were produced on the tetraploid of seedling clone 209. These flowers range from 10 to 12 inches in length and 6 to 7 inches across the open trumpet.

These four tetraploid clones have been selected not only for their flowers but also because they produce a very high percentage of single-nose bulbs. All the commercial varieties now available regularly produce a high percentage of double- and triple-nose bulbs.

Tetraploids of the commercial varieties Croft, Ace, and Estate have not yet produced enough flowers for an accurate determination of their value.

Cytological Observations

The chromosomes of *Lilium longiflorum* are shown in Fig. 2. They were drawn from root-tip smears prepared by the technique described by Emsweller and Stewart (2). It can be seen that chromosomes A to H are readily distinguishable from all others; but I and J are practically identical, and this is also true of K and L. A somatic diploid cell is shown in Fig. 3A. The two small fragments were produced by chromosome breaks, one at the secondary constriction of E and the other at the secondary in the long arm of D. These induced fragments were caused by excessive pressure on the cover glass during preparation of the slide. All such breaks observed occurred at a secondary constriction, which indicates a relative weakness of the chromosomes at that point.

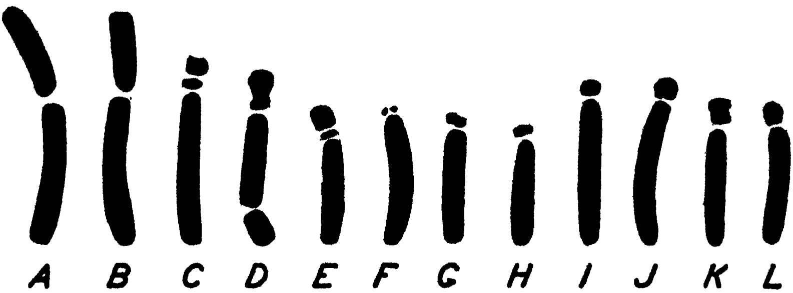

Fig. 2. Chromosomes of Easter lily *(Lilium longiflorum)*.

The eight aneuploid plants were of six types with regard to the chromosomes present. The 4n — 3 plant was deficient for one each of the A, E, and I-J chromosomes. It is, of course, impossible to state whether the improved flower quality of this plant resulted from the lack of these three chromosomes. The 4n — 2 plant had one A and one D chromosome missing. Three of the five 4n — 1 plants lacked an E chromosome, one of the remaining two was deficient for an I-J, and

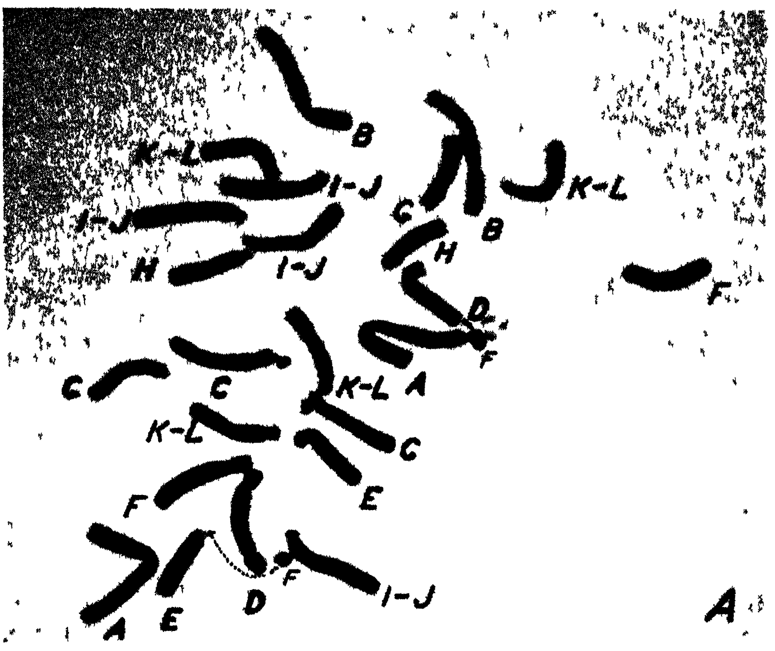

FIG 3 A, Diploid cell of Easter lily *(Lilium longiflorum).*

the other for an F The $4n + 1$ plant had an extra I-J chromosome. The cell in Fig. 3B is from a plant deficient for an E chromosome. Fixation of this cell occurred just as the 47 chromosomes were splitting and the constrictions are very clear.

DISCUSSION AND SUMMARY

The size and substance of Easter lily flowers are of considerable economic importance As a rule large flowers are preferred and those with thick petals are especially prized. Such heavy flowers can be handled rather roughly because they have what the florists call "substance". Many otherwise good lilies are rated very low because the petals are thin and the flowers are said to be "soft".

The tetraploids described in this paper all have very thick petals and flowers from one-fourth to two-thirds larger than the corresponding diploids. It was found that some tetraploids showed very little improvement over their respective diploids, whereas others were greatly superior. For this reason it is advisable to make a large number of tetraploids and select the best among them.

The fact that aneuploidy results from colchicine treatments adds further incentive for thorough exploration of the possibilities of induced polyploidy in asexually propagated flowering and ornamental plants.

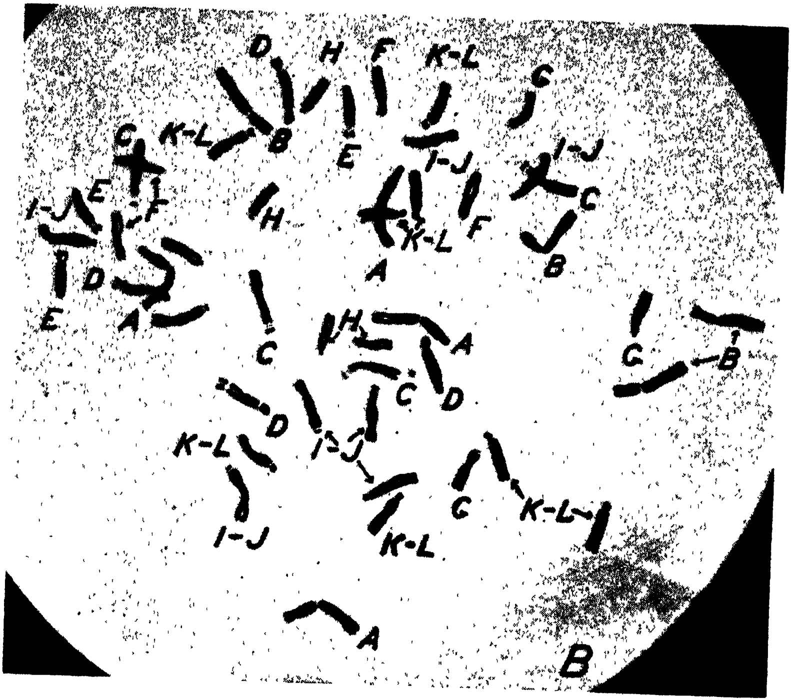

FIG. 3. B, a cell from a 4n — 1 plant in which one E chromosome is missing.

Since Easter lilies can be propagated very rapidly by bulb scaling (3), these tetraploids will soon be available in large quantities.

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Selection Within A Gardenia Clon

By J. R. KAMP and F. F. WEINARD, *University of Illinois, Urbana, Ill.*

IN a gardenia spacing experiment previously published (1), the yields for a two-year period varied from as low as three flowers per plant to as high as 175 flowers per plant. Although the plants were presumably all of one clon, known in the trade as McLellan No. 23, the differences in yield between individual plants were so great that it was decided to propagate and keep a record of performance of individual clons.

METHODS

It was recognized that position of gardenia plants on the bench and also the spacing of the plants have important effects on yields. Therefore, high-yielding and low-yielding plants were chosen for propagating from each longitudinal east and west row in the bench. Cuttings were taken in January 1945, and the new plants were benched on June 28. The planting included nine clons from high-yielding plants and five clons from low-yielding plants. The plants were set 24 inches by 14 inches in a bench filled with haydite and subirrigated with a nutrient solution. They were so spaced that equal numbers of each clon were located in the south, center and north rows. They were also evenly distributed from end to end of the bench, in an effort to minimize the effects of differences in temperature. The bench was located on the south side of an east and west house. Roses were grown in the other benches and the house was maintained at rose-house temperatures.

Records were kept of flower production by individual plants from October 1, 1945 until July 1, 1946.

RESULTS

As noted in previous experiments the south row in the bench gave by far the highest yield. The average was 37.1 flowers per plant, as compared with 15.2 flowers per plant in the center row and 12.4 flowers in the north row.

That the west end of the house was several degrees warmer than the center and the east end was also reflected in the yields. The average yield in the west third of the bench was 26.8 flowers per plant, as compared with 19.3 flowers per plant in the center and 18.9 flowers in the east section.

The yields of the clonal selections are given in Table I. The clons which might be expected to give the larger yields averaged 20.3 flowers per plant, and the clons selected for low yield averaged 26.4 flowers per plant.

DISCUSSION AND CONCLUSIONS

In the flowering season of 1944–45 there were wide differences in yield noted in plants very close together on the bench and apparently receiving about equal amounts of heat and light. This led to the belief

TABLE I—FLOWER PRODUCTION BY GARDENIA CLONS SELECTED WITHIN A VARIETY

Clon	Number of Plants	Yield Per Plant
High	9	19.8
High	12	23.8
High	7	24.7
High	14	22.1
High	15	18.7
High	9	19.0
High	12	15.9
High	12	20.7
High	7	18.1
Average		20.3
Low	2	37.5
Low	14	23.5
Low	10	20.0
Low	11	24.8
Low	12	26.3
Average		26.4

that the differences in yield might be due to some genetic factor, and to an attempt to propagate from high and low yielding clons.

It was assumed that by proper spacing of the plants in the bench the effects of environmental conditions on the yields of each clon could be eliminated. Then, if there were genetic differences the highest yield in the 1945–46 season should have been from the plants from so-called high-yielding clons. If there were no genetic differences, the yields from all clons should have been approximately the same. Since neither of these conditions were found to exist, it seems that there must be at least one additional environmental factor which was not controlled.

The observed results might have been influenced by environmental conditions in the cutting bench. All cuttings from a single clon were bunched together in the cutting bench rather than being spaced out as they were in the final planting. Thus, if there were local conditions favorable or unfavorable to rooting, certain clons might have been given an early advantage which was not discernible at time of planting but which might have influenced the season's yield of flowers.

We conclude, therefore, that either position on the bench or some other environmental factor so strongly influenced yields of flowers as to mask any possible genetic differences and thus make the selection of a clon within a clon extremely difficult under ordinary greenhouse conditions.

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"Time Pinching" Chrysanthemums

By VERNON GIFFORD and D. C. KIPLINGER, *Ohio Agricultural Experiment Station, Wooster, O.*

"TIME PINCHING" is a new development in the growing of chrysanthemums. Instead of pinching when the plants are from 6 to 8 inches tall, the plants are pinched according to the calendar, the later the date of maturity, the later the pinch. This necessitates that early varieties be planted first, and the later varieties be planted later if the single time pinch is to be used.

A crown bud generally develops in standards if they are not pinched or if they are pinched according to the old method. This bud is usually removed and one of the vegetative shoots around it is allowed to develop which ultimately produces the terminal bud. Preliminary tests have shown that if the pinch is made at the right time the crown bud never forms and the result is a straight stem without any joints or crooks which are usually present when a crown bud develops.

In pompon chrysanthemums a crown bud may also develop at some point during the growth of the plant unless the pinch is made at the right time. Preliminary tests indicated that if the pinch is made too early a crown bud may develop early and the vegetative shoots around it would have a long growing period and as a result these shoots would be of uneven lengths and would not present an even, well balanced spray. If the pinch is made too late only a terminal bud may form which in many cases produces a spray with only a few flowers. If the pinch is made at the right time the crown bud may develop late in the growth of the plant. The shoots around the crown bud would then have a shorter growing period and the result would be a more even and well balanced spray.

Hand in hand with time pinching is the idea of limiting the number of stems per plant. In the past the custom was to pinch as many times as was possible to get the maximum number of stems per plant. However, it is now known that by limiting the number of stems to two, three, or four per plant, the quality of pompons can be greated enhanced.

The work reported in this paper is a summary of the tests carried on at the Ohio Agricultural Experiment Station at Columbus during 1946.

PROCEDURE

Cuttings for these various time pinching tests were handled in one or two ways. Some of the plants were grown in gravel culture. These were received as rooted cuttings and were benched direct. The others that were grown in soil were received as unrooted cuttings and were potted in 2½ inch pots in a light soil mixture. Three weeks time was allowed for rooting although most of them were well established in 2 weeks.

All standards were planted 6 by 8 inches, given a single pinch and were grown to a single stem. The pompons planted in soil were spaced 7 by 8 inches, given a single pinch and were grown two stems per plant. The pompons in gravel culture were handled in two ways. Half a bench was spaced 7 by 8 inches, given a single pinch and grown two stems per plant. The other half bench was spaced 8 by 9 inches, given a single pinch and grown four stems per plant.

A planting and pinching schedule was worked out for the various varieties used. This schedule and some results are given in Table I.

The first three varieties listed in the table were shaded and were given a single pinch 33 days prior to shading. The other varieties listed were allowed to flower naturally. Each variety was divided into three plots, each planted a week later than the previous one, and each plot was pinched approximately 3 weeks after the date of planting. For each variety there were three different planting and pinching dates.

DISCUSSION OF RESULTS

Inasmuch as these time pinching tests were concerned with crown bud formation an attempt was made to record the number of crown and terminal buds formed on each plot, this information is given in Table I. It can be seen from the figures in the table that the majority

TABLE I—PINCHING DATES AND THEIR RELATION TO CROWN BUD FORMATION*

Planting Distance (Inches)	Date of Potting Unrooted Cuttings	Date of Benching	Date of Pinching	No. Stems Per Plant	No. Crown Buds	No. Terminal Buds
		Rusticon				
7×8	R/c	May 29	Jun 28	2	0	322
8×9	R/c	May 29	Jun 28	4	0	466
		Omega				
7×8	R/c	May 29	Jun 28	2	-	—
8×9	R/c	May 29	Jun 28	4	125	363
		Souvenir				
7×8	R/c	May 29	Jun 28	2	0	308
8×9	R/c	May 29	Jun 28	4	0	453
		Bittersweet				
7×8	Jun 5	Jun 28	Jul 19	2	36	245
7×8	Jun 12	Jul 5	Jul 26	2	4	296
7×8	Jun 19	Jul 12	Aug 2	2	4	301
		Goldsmith				
7×8	Jun 18	Jul 18	Jul 29	2	253	37
7×8	Jun 25	Jul 15	Aug 5	2	222	105
7×8	Jul 3	Jul 22	Aug 12	2	232	102
		Cameo				
7×8	Jun 18	Jul 10	Jul 31	2	162	48
7×8	Jun 25	Jul 17	Aug 7	2	167	5
7×8	Jul 3	Jul 24	Aug 14	2	230	3
		Marketeer				
6×8	Jun 10	Jul 3	Jul 25	1	188	0
6×8	R/c	Jul 11	Aug 1	1	160	0
6×8	Jun 25	Jul 18	Aug 8	1	205	0
		Harvester				
6×8	Jun 18	Jul 8	Jul 29	1	0	186
6×8	Jun 25	Jul 15	Aug 5	1	0	186
6×8	Jul 3	Jul 22	Aug 12	1	0	186

*Date of shading—August 1 to September 16.

of buds formed on the first three varieties, Rusticon, Omega and Souvenir, were terminal buds. The pinch was made 33 days before shading, this was close to the number (35) usually recommended for early varieties. However, these are mid-season to late varieties, for which the pinch should be made 40 days before shading. It is believed that if the pinch had been made earlier, more crown buds would have formed. The spray formation resulting from the formation of a terminal bud on the above varieties was satisfactory but not quite as good a spray as might be expected from a crown bud. The one plot of Omega produced about one-third crown buds and two-thirds terminal buds. The crown bud developed late in the growth of the plant and bloomed with flowers on the branches around it. It was an even, well balanced spray with a larger number of individual flowers than was on the spray resulting from the formation of a terminal bud.

The type of spray on both the 2- and 4-stemmed plants was essentially the same. There was a slightly higher percentage of salable stems on the plants grown to two stems than on the plants grown to four stems, but not a sufficient difference to be of any significance. Plants grown to two stems were easier to bunch than plants grown to four stems due to the more uniform height and weight of each stem.

Bittersweet:—The first pinching date on Bittersweet gave the best results. More crown buds were formed on the first plot than on the other two although this number was not very high. The fact that the number of crown buds on the second and third plots was considerably less than on the first plot is an indication that the time of pinching was too late. If the first pinch had been made a week earlier than the one listed in Table I, there probably would have been more crownbuds. The two types of sprays resulting from the formation of a crown and terminal bud were both satisfactory. However, the spray resulting from a crown bud had a better shape and more flowers and was better than a terminal type spray. The stems of the plants in all the plots were longer than is necessary for commercial purposes and it is believed that this variety could be grown to four stems to good advantage.

Goldsmith:—Goldsmith was grown somewhat as a disbud. The plants were given a single pinch, grown to two stems per plant, and disbudded to four to six flowers per stem. The first pinching date resulted in the formation of more crown buds than terminal buds. All three plots produced more crowns than terminals, but there was a higher percentage of terminals in the second and third plots than in the first plot. The highest number of desirable sprays was found in the first plot which is an indication that the pinch was made at the right time.

Cameo:—A few terminal buds were formed on all three plots of Cameo, but the highest number was in the first plot. This number was not too high so any of the pinching dates used would be satisfactory for Cameo. The fact that a high number of crown buds was formed quite late in the growth of the plants could be interpreted to mean that a high number of desirable type sprays could be expected. However, this was not the case with Cameo. The side shoots had a tendency to grow out from the stem almost at right angles and then curve upwards. This gave a spray with an antler-like appearance that was difficult to cut and bunch and in general was not too desirable.

Harvester and Marketeer:—The three pinching dates on Harvester were all effective in eliminating the crown bud for only terminal buds were formed. This is desirable with standards for the result is a straight stem.

The results with Marketeer were just the opposite. The three pinching dates on Marketeer did not eliminate the crown bud in any of the plants. In fact, on many of the plants a crown bud formed before the time of pinching and another one later on. Records of other varieties indicate that not all are affected by the time pinch.

Orchid Queen:—Other tests included the effect of time pinching when additional light was used to retard flowering. Several varieties were used, but the results with Orchid Queen are particularly interesting. The benching, pinching, and lighting dates and results are shown in Table II.

TABLE II—ORCHID QUEEN

Date of Benching	Date of Pinching	Lighting		No. Crown Buds	No. Terminal Buds
		Wattage	Time		
Jun 28	Jul 19	25	Aug 10–Sep 10	0	42
Jul 8	Jul 29	25	Aug 10–Sep 10	0	35
Jun 28	Jul 19	25	Aug 10–Oct 10	32	3
Jul 8	Jul 29	25	Aug 10–Oct 10	28	8
Jun 28	Jul 19	100	Aug 10–Sep 10	0	42
Jul 8	Jul 29	100	Aug 10–Sep 10	0	47
Jun 28	Jul 19	100	Aug 10–Oct 10	31	9
Jul 8	Jul 29	100	Aug 10–Oct 10	19	24

From the table it can be seen that under both 25 and 100 watt lamps, for the 30-day lighting period and for both pinching dates, only terminal buds developed. However, when the duration of the lighting period was extended to 60 days, many more crown buds were formed. But it must be noted that fewer crown buds were formed as a result of the later pinch, and this is especially evident under the 100-watt lamps.

GENERAL SUMMARY AND CONCLUSIONS

In general, the results obtained this year support and coincide with results in 1945. The time pinch, if made at the right time does eliminate the crown bud on some varieties of standards. However, some varieties appear to be unaffected by the time pinch.

The results this year also indicate that if the pinch is made at the right time on pompons, a crown bud will be formed late in the growth of the plant and this will result in the formation of a very desirable type spray. The results also indicate that if the pinch is made too late, only terminal buds may be formed which usually do not produce as desirable a type spray. On the other hand, if the pinch is made too soon, a crown bud may develop early in the growth of the plant. The shoots surrounding it will then have a long growing period and the result may be a poor, uneven formed spray.

Some precautions are necessary when using the time pinch. The time of pinching will to a certain extent govern the time of planting. To cite an example, assume that cuttings are benched June 1, but the pinch date is not until July 4. By that time the plants might be from 12 to 18 inches tall. Obviously, if only the very tip of these plants is pinched out the plants will be extremely tall at maturity. On the other hand if they are pinched back to about 6 or 8 inches the stem would be extremely hard and the buds would be slow in breaking. So if the plants become very tall before pinching, a little common sense must be used and strike a medium somewhere between the two extremes mentioned above.

Two or three weeks time at the most is sufficient time to allow between benching and pinching of many varieties. Therefore, after the pinching date has been established it will be a simple matter to count back 2 or 3 weeks to get the time for planting. The late maturing varieties are pinched much later than early varieties. Therefore, it becomes necessary to plant progressively later depending on the date of maturity.

Much remains to be learned as to just why and how the time pinch works, but it does appear to be means of securing high quality in chrysanthemums.

Changes of Rooting Response in Cuttings Following Exposure of the Stock Plants to Light of Different Qualities

By V. T. Stoutemyer and Albert W. Close, *U. S. Plant Introduction Garden, U. S. Department of Agriculture, Glenn Dale, Md.*

Discussion in recent years of treatment of cuttings to induce rooting seems to have diverted attention somewhat from the old gardener's solicitude for the condition of the plant from which the cuttings are taken. This is always tacitly recognized by the timing of making the cuttings and experienced gardeners have been aware that with some species better rooting is obtained with cuttings taken from plants grown under glass than with those taken from plants growing outside.

In a previous report by the authors (1), exposure of cuttings to light of different spectral qualities was found to cause large differences in the heaviness and speed of rooting of cuttings. In general, a light having a high proportion of radiation in the red end of the spectrum was found to be best. In the present study, irradiation of the stock plants for a period of about 6 weeks before taking the cuttings was found to exert a striking influence on both root and callus formation.

A common difficulty in rooting some types of woody cuttings is the production of excessive basal callus, which may prevent rooting or delay it for a long time. This difficulty is present with many coniferous and broad-leaved evergreens, as well as other woody plants, and some propagators lift the cuttings and pare off the callus occasionally as an aid to rooting.

Gordonia axillaris was chosen as a test plant in studying this phenomenon, since excessive callus is common with cuttings of it, especially at some seasons of the year. The evergreen foliage of this plant allowed tests to be conducted over most of the year. In the experiment now reported, the potted stock plants were divided in five lots, with the control held in a cool greenhouse. The other lots were placed on December 6, 1945 in an opaque, semi-underground shed described in a previous publication (1) under metal fluorescent fixtures each holding two 40-watt lamps. The temperature was around 58 to 60 degrees F most of the time, but occasionally went a few degrees higher. The relative humidity in this shed was well above 90 per cent at all times. The plants were illuminated for 16 hours daily. The plants were about 2 feet high and the upper leaves were close to the fluorescent lamps and thus received a maximum light intensity of about 700 or 800 foot candles with daylight tubes as read by a Weston Illumination Meter. Naturally the light diminished rapidly on the lower leaves, both because of the distance and the shading by the upper leaves. The combinations of light used were as follows: two daylight tubes, one pink and one blue tube combined, two blue tubes, and two "E" phosphor General Electric sunlamps.

The cuttings were removed on January 14, 1946 and placed on an open greenhouse bench in sand. A thermostatically controlled lead-sheathed soil heating cable held the temperature close to 70 degrees F. At the time these cuttings were made there were no noticeable differences in appearances between the different lots, with the sole exception that some leaf injury and abscission had taken place under the "E" phosphor lamps.

The cuttings were removed and graded in classes according to the heaviness of rooting on June 6th. The results are shown in Table I.

TABLE I—Rooting of Cuttings of *Gordonia axillaris* as Influenced by Exposure of the Stock Plants to Light of Different Qualities

Light Quality	Total Number	Total Rooted	Number Rooted			Number Alive Not Rooted	Remarks
			Heavy	Medium	Light		
Greenhouse grown	23	20	3	3	14	3	Excessive callus; light roots
Daylight tubes	22	14	3	4	7	8	Excessive callus, light roots
Blue and pink tubes	24	17	12	1	4	7	Fair roots; moderate callus
Blue tubes	42	30	17	8	5	12	Little callus; heavy roots
"E" phosphor General Electric sunlamps	30	23	9	3	11	7	Little callus; fair roots

When the cuttings were removed (June 6), striking differences in the type of callus and of root formation were evident. The cuttings from plants grown in the greenhouse had large masses of callus, but the root systems were comparatively scanty for the most part, consisting in many cases of only one or two short roots. The cuttings from the plants grown under the daylight tubes showed considerable similarity in the rooting response and in the amount of callus formation. Development of callus was reduced considerably in the cuttings from plants grown under the combination of a pink and a blue tube. By far the best rooting, together with the formation of almost no callus, was found in the cuttings from the plants grown under the two blue tubes. The "E" phosphor General Electric sunlamps were somewhat injurious to the foliage and caused some dropping of the leaves. Rooting was not particularly heavy in cuttings taken from this lot. However, there was little callus formation.

The similarity in the callus and root formation between plants grown in the greenhouse and under daylight fluorescent lamps is shown in Fig. 1. The marked improvement in rooting caused by growing the stock plants under blue lamps is also shown in this photograph.

Similar tests with *Salvia splendens,* a herbaceous plant, were inconclusive. However, similar tests with cuttings made from seedlings of *Cinchona Ledgeriana,* partially lignified, showed heavier rooting in the lots grown under blue fluorescent tubes. Excessive callus formation was not a problem with this species.

Further experimentation will be necessary to determine the influence of different photoperiods and also different total treatment periods for the stock plants. These results should be regarded as only preliminary in nature, but they indicate a possible solution to a re-

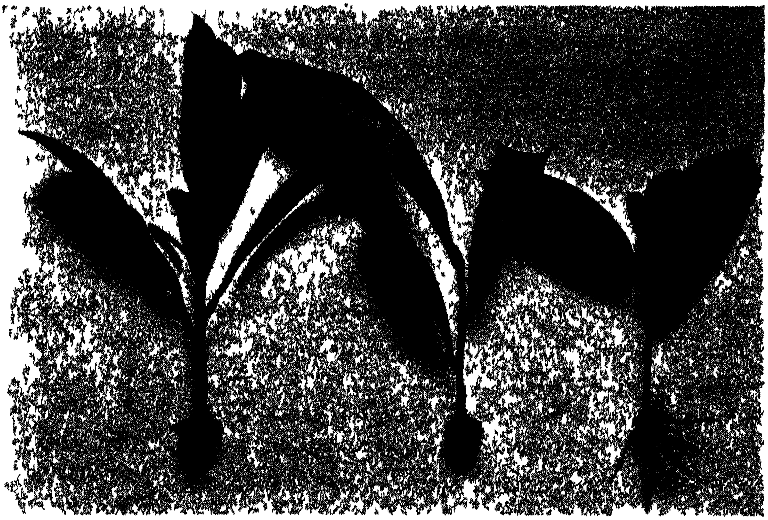

FIG 1 Cuttings of *Gordonia axillaris*. Left: Cutting from greenhouse grown plants Center· Cutting from plants grown under daylight tubes. Right: Cutting from plants grown under blue tubes

curring, difficult problem in the handling of cuttings of many kinds of woody plants. Since the action of the General Electric "E" phosphor lamps was somewhat similar to that of the blue tubes although the spectral distribution is very different, it is possible that the important factor may be the exclusion of a certain band of radiation in the red end of the spectrum, rather than the effect of a specific band in the blue end. Oddly enough, blue light was usually the least favorable light for cuttings during the rooting period in the previous experiments of the authors (1), when applied after the cuttings were placed in the rooting medium.

LITERATURE CITED

1 STOUTEMYER, V. T, and CLOSE, ALBERT W Rooting cuttings and germinating seeds under fluorescent and cold cathode lighting. *Proc Amer Soc Hort Sci* 48 309–325 1946

Copper Tube Surface Automatic Watering[1]

By KENNETH POST, *Cornell University, Ithaca, N. Y.*, and PARKER F. SCRIPTURE, *Revere Copper and Brass Company, Rome, N. Y.*

AUTOMATIC watering enables growers to keep the soil at nearly constant, uniform moisture with no labor cost. The system of automatic watering as developed by Post and Seeley (1) requires a water tight bench. Many florists and nurserymen wish to use automatic watering but the cost and difficulties of getting a water tight bench prevents them from converting to this method of watering.

This paper presents the development and application of a method of automatic watering involving a copper tube for distributing the water throughout the length of the bench. The copper tube is perforated with small holes, at intervals throughout the length, to supply water to the surface of the soil at a very slow rate. The water moves laterally in the soil by capillary movement and wets the entire volume, giving little or no drainage water through a depth of 5 inches of soil. This system of automatic watering has been adapted to many types of benches, both level and sloping, and to soils of various types. It also has application in propagating benches, watering of nursery stock and garden plants.

LAWN SUBIRRIGATION

Originally a project was established for the purpose of developing a perforated copper tube subirrigation system for the purpose of watering lawns and golf greens.

During the Summer of 1944 preliminary experiments were made at Rome, New York to determine the lateral movement of soil moisture in a lawn plot. Copper tubes 20 feet long were laid at depths of 1, 3, and 6 inches below the soil surface and parallel to each other on 6-foot centers. Orifices of .020 inches diameter had been drilled in the tubes at 30-inch intervals. Water was supplied to the system through a header at 1½ pounds per square inch pressure. Rain was kept off the test plots by canvas tents. Tensiometers (2) placed in the soil near the tubes showed sufficient moisture for good grass growth. Tensiometers midway between the tubes showed excessive drying.

Subsequent tests to determine proper distances between tubes and orifices in the tubes were conducted in specially constructed greenhouse benches as well as out-of-door plots. Effective lateral movement of moisture in clay and silty soils was found to be less than 1 foot. This would require placement of parallel tubes on centers at less than 2 feet. Sandy soils, however, showed greater conductivity of water horizontally by capillarity than the finer particled soils.

Channels of "brick" sand placed below the surface in clay and silt soils and leading away from orifices in the tube aided in lateral moisture distribution. Tubes on 4-foot centers satisfactorily irrigated a heavy clay soil when subterranean sand channels were employed.

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[1] The supplies and equipment for this project were made available by Revere Copper and Brass Incorporated, Rome, N. Y.

Puddles of water which normally accumulated on the soil surface over the orifices in the clay soil, were eliminated when the sand channels were used.

The growth of grass was unsatisfactory within a radius of 6 to 8 inches from the underground orifices. Moreover, the soil was so soggy that a normal footstep in the 6- to 8-inch radius seriously deformed the sod surface. The use of the sand did not alleviate either of these two problems.

The most serious problem, however, was presented by the mechanical stoppage of flow from the orifices. Tubes that had been used underground were found to have a layer of silt in the bottom which prevented the discharge of water through the orifices. It is believed that this silt worked back through the orifices as soon as water discharge was stopped and while there was gravitational water in the soil around the orifices. Various means employed to keep these fine soil particles from working into the small orifices were unsuccessful. Filters that kept the silt from working into the tubes eventually kept the water from flowing out the orifices.

It was during the course of these investigations that the herein described method of watering florists' benches was worked out.

HORIZONTAL CAPILLARY MOVEMENT OF SOIL MOISTURE

Comparison of Lateral Moisture Movement in Various Soils:— Three watertight V-bottom benches, 12 feet by 15 feet by 12 inches deep, pitched to drain to one end, were partially filled with ¼- to ½-inch crushed stone to level the bottom. Each was then filled to the top with heavy clay loam, silty loam and loamy sand respectively. The benches were each flooded and drained three times to assure a natural compacting of the soil. Mercury manometer tensiometers were employed to determine the available soil moisture. Water was metered and pressure was constantly maintained by use of a pressure reducing valve. Half-inch copper tubes, each with one .031-inch diameter orifice supplied water to the benches.

The orifice in the tube was placed in the center of the bench to emit water 2 inches below the soil surface. Tensiometers were placed to measure capillary tension at a depth of 2½ inches below the soil surface and at distances of 1, 1½ and 2 feet from the point of water emission. Water was discharged from the orifice at 1½ pounds pressure and at an average rate of 0.068 cubic feet per hr. Tensiometer readings were recorded until water drained through the soil at which time the water was turned off. One test on each soil type was conducted when the average tensiometer reading at the 2½-inch depth was 3 inches of mercury and one test was conducted on each soil type when the average reading was 6 inches of mercury, which we refer to in the following paragraph as 3-inch test and 6-inch test respectively.

None of the tensiometers in the clay and silt loam benches indicated a soil moisture increase at any time during the test, even at 1 foot from the point of injection. Tensiometers in the loamy sand indicated an increase in soil moisture, in both the 3-inch and 6-inch tests at 1 foot (but not 1½ feet) from the point of injection. Percolation to the bottom of the bench was slower in the 6-inch tests than in the 3-inch tests in all three types of soil; therefore, a greater quantity of water was injected into the drier soils. In the case of the 6-inch test in the loamy sand, this greater quantity of water resulted in an increase in soil moisture at a distance of 1½ feet from the point of injection 2 hours after the water injection was stopped.

Evidence is here shown of good lateral capillary movement of soil moisture in the sandy soil as compared with the finer particled. silty and clayey soils. The larger grain size of the sand and the consequently larger void spaces between the particles, permitted the more ready movement of soil moisture by capillarity.

Effect of Sand Layer on Surface of Composted Greenhouse Soil:—Two adjacent test plot areas, 4 feet by 4 feet in a ground bed were used for this experiment (Fig. 1). The ground bed was composed of a 6-inch depth of composted silty loam soil imposed on a gravelly subsoil. Roses, planted three years previously, were growing in this bed. A layer of "brick" sand, 1½ inches deep, was placed on the surface of one plot. The other plot, without the sand layer, served as a check. Two ⅜-inch copper tubes, connected to a pressure regulated source of water, were laid parallel to each other 2 feet apart and horizontally on the surface of the two plots. Each tube had four orifices, 2 feet apart, of .031 inches diameter and was turned so that the orifices were on the bottom permitting a jet of water to be expelled downward. One tensiometer was placed, to measure capillary tension 2½ inches below surface, in the center of each of the two test plots.

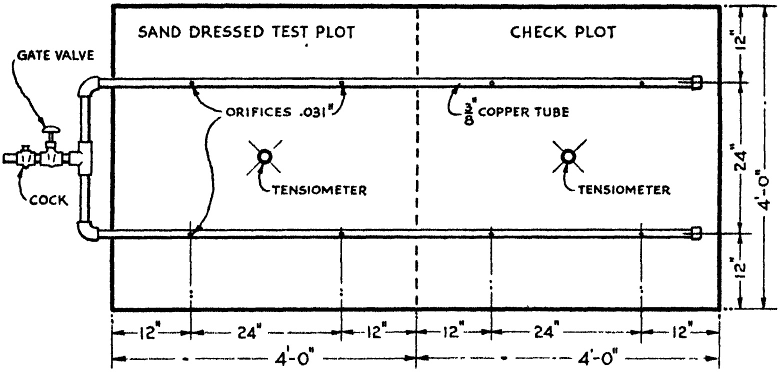

FIG. 1. Layout of experimental tube irrigated plots with and without a sand layer.

Water was directed into the tubes under a pressure of 1½ pounds per square inch for a period of 8 hours and tensiometer readings recorded throughout the period with the results as given in Table I.

The original capillary tension was greater in the check plot and this may have retarded the rate of lateral moisture movement. Nevertheless the sand layer appears to have increased the movement of water.

Effect of Sand Layers at Various Levels in the Soil:—In three plots, layers of brick sand, ½ inch, 1 inch and 2 inches deep respectively,

TABLE I—COMPARISON OF HORIZONTAL CAPILLARY MOVEMENT OF WATER IN SOILS WITH AND WITHOUT TOP DRESSING OF BRICK SAND

Hours Elapsed From Beginning of Water Discharge	Capillary Tension (Inches of Mercury)	
	Sand Dressed Test Plot	Check Plot
0.00—discharge started	3.75	6.25
1.33	3.50	6.25
2.08	3.25	6.25
2.92	2.50	6.25
4.33	1.25	6.25
5.83	0.75	6.25
7.00	0.50	6.25
8.00—discharge stopped	0.50	5.50
24.00	0.75	4.25

were placed in the bottom of a raised bench 36 inches wide. The remainder of the bench was filled with a 5-inch depth of composted soil. In another series of plots, a 5-inch depth of composted soil was covered with layers of brick sand to ½-, 1- and 2-inch depths.

In both treatments perforated copper tubes were placed on top of the combined stratas with the orifices opening downward.

Water was injected in the copper tubes at 1, 2, and 3 inches of tension. The sand layers placed on the surface of the soil gave good lateral movement of water and uniform moistening of the soil in all treatments with little drainage water before the soil was moist.

Sand in the bottom of the bench had little effect on wetting the soil. Apparently water did not move upward by capillarity from the sand layer in sufficient amounts to moisten the soil before excessive drainage occurred. Without the sand layer on the soil it was possible to wet the soil only about 6 inches from the orifice.

DEVELOPMENT OF THE METHOD

Direction of the "Fountain":—During the course of experiments at both Ithaca and Rome, New York, these phenomena were observed:

1. When the direction of the stream of water from the perforations in the tube was pointed downward, the stream "drilled" a hole in the sand layer and/or soil.
2. When the orifices opened downward many of them were stopped completely by an air-bound condition and by an accumulation of particles in the bottom of the tube.

By revolving the tube through 180 degrees so that orifices pointed upward, these results were noted:

1. The ejected water or "fountain" was impelled upward, broke slightly at its apex and broomed out in many directions, thus covering an area much larger than the pinpoint area of injection of a downward pointed stream: this dispersion of the stream entirely eliminated the "drilling" of the soil.
2. The tubes vented themselves completely and water was expelled from all the orifices without the air-bound effect. Particles in the water which are heavier than the water accumulated in the bottom of the tube and did not tend to restrict the orifices.

Size and Location of Orifices:—The exact size of orifices was not found to be vitally important so long as these requirements were adhered to:

1. Orifices must be small enough to prevent a "gush" of water from flooding the soil beneath them.
2. They must be small to enable smaller and consequently lower cost tubes to carry the water reasonably uniformly to all of them.
3. They must be large enough not to be plugged readily by silt particles or to be too readily restricted by precipitates from the water supply.
4. They must be of uniform size in order to assure reasonably uniform discharge from all of them.

Through practical trial over relatively short periods of time (one year or less) orifices .036 to .044 inches in diameter were observed to give the required results with a standardization being made at .039 inches diameter.

Trials by Commercial Growers:—While this method of irrigation had been successful at Rome and Ithaca when operated by the authors during periods of low evaporation rates from the soil and plants, its practicality in the field under varying circumstances of personality, of soils and of other unforseen conditions, was yet to be found. Moreover, it was deemed desirable to standardize specifications so that irrigation requirements under practically all conditions could be satisfied.

Nine commercial growers cooperated by making trial installations in rose benches and three other growers made trial installations for other applications.[2] In all installations the water was turned on and off manually. Installations in rose benches consisted, on the one hand, of one line of tubes, with perforations every 3 feet in a 48-inch wide bench, to the other extreme, of two parallel tubes with perforations every 18 inches in a 42-inch wide bench. Installations were made in raised and in ground benches, in wooden and in concrete benches, in benches having a slope of more than 1 foot in 100 feet, in benches containing very porous, highly organic soil as well as benches having highly compacted heavy soils.

Most of these installations were made in June 1946 so that the moisture carrying effect of the sand blanket could be observed during that period of the year when almost daily surface watering was necessary. In November 1946 the cooperating rose growers reported their findings, a summary of which is contained in Table II.

From a study of Table II these observations may be made:

1. Even though the soil has a high sand content (Grower H), it is not necessarily a good capillary medium. Undoubtedly, the numerous fine particles incorporated with the sand so reduce the size of the void spaces as to preclude good capillarity. Grower J, without the sand layer on the silty-clay bench soil, reported com-

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[2] The authors gratefully acknowledge the cooperative assistance rendered by Harry L. Allyn, Big Flats, N. Y.; Frank J. Baker & Sons and Brant Brothers, Inc., Utica, N. Y.; Jackson & Perkins Co., Newark, N. Y.; Maier's Greenhouses, Wantagh, L. I., N. Y.; Nielsen's Greenhouses and Ivar Ringdahl, Rome, N. Y.; Rose Fair, Inc., Blue Point, L. I., N. Y.; Tanner's Flower & Gift Shoppe, Holland, N. Y.; United State Cut Flower Co., Elmira, N. Y.; The Wheatley Gardents, Greenvale, L. I., N. Y.; and White Bros. Rose Corporation, Medina, N. Y.

TABLE II—SUMMARY OF REPORTS FROM COOPERATING COMMERCIAL ROSE GROWERS

Grower	Distance Between Orifices	Number of Lines of Tubes in Bench	Bench Width (Inches)	Bench Type	Does the Sand Layer Carry the Moisture to the Sides of the Bench?	Does the Method Show Enough Saving in Labor to Warrant Its Installation?	How Does Production Compare With Hand Watered Check Benches?
A	18	2	42	Raised*	Yes	Yes	Same
B	24	2	39	Ground	Yes	Yes	Same
C	24	2	42	Ground	Yes	Yes	Definitely better
D	29	2	54	Ground	Yes	Yes	Same
E	36	2	44	Ground	Yes	Yes	Same
F-1	36	2	48	Ground	Yes	Do not know	Same
F-11	24	1	38	Ground	Yes	Do not know	Same
G	36	1	48	Raised	Yes	Yes	Slightly better
A**	36	1	42	Raised	No	—	—
C**	24	1	42	Ground	No	—	—
H†	36	2	48	Ground	—	—	—
J‡	36	2	52	Ground	—	—	—

*This bench has a slope of 22 inches in 110 feet; by placing the cross header at the high end of the bench, a uniform fountain height was obtained throughout the two lines of perforated tubes.

**These are the original installations for Growers A and C. Revision of these installations gave the results as indicated opposite the first listing of A and C.

†No sand layer was used—soil was sandy—results were obtained by applying excess quantity of water.

‡No sand layer was used—soil was clayey—no amount of watering gave desired results.

plete failure.

2. In the 6-month trial period, all seven growers using the sand layer report production at least as good in the tube irrigated bench as in the check benches.
3. Six of the seven growers using the sand layer report a saving of labor sufficient to warrant the cost of installation of the system.
4. The original installations of Growers A and C were unsuccessful. The soil in these cases was very porous and permitted drainage before capillary water reached the edge of the bench.
5. Grower G used a single tube with orifices 36 inches apart to irrigate a 48-inch wide raised bench and obtained practically no drainage of water. Two factors may account for this success: one, the layer of sand is 1¼ to 2 inches deep (deeper than most) and, two, the soil is highly compacted and appears to be comparatively impervious to the percolation of water.
6. No failure was reported in any of the trials where two lines of tubes were used. It is possible that failures might have resulted had Growers A and C used tubes with orifices 36 inches apart. There is nothing to indicate that Grower A could not have successfully used orifices 24 inches apart. Placement of orifices every 24 inches undoubtedly provides an ample margin of safety for most benches.

DISCUSSION

Problems of Permanency:—It is believed that orifices in copper tube will prove to be fairly long lived except in these circumstances: corrosion may be induced through spreading fertilizer in certain forms on the tubes; in unusual situations, the chemical content of the water may induce corrosion or deposit irremovable precipitates in the throat of the orifice. A precipitate of calcium carbonate can usually be removed by forcing a common pin through the orifice.

Comparatively little is known as to the effective life of the sand layer as a vehicle for carrying the moisture horizontally by capillarity. When first applied, clean brick sand is effective in carrying moisture over the entire surface of the bench within 1 to 2 hours, depending on the particular size of the sand grains, the texture of the subsoil and the rate of discharge of water from the orifices. While all the installations appear to be working satisfactorily in this respect, the longest consecutive trial period to date is but 6 months. It is possible that materials such as decayed leaves, decayed weeds, earthworm castings, chemical fertilizers or any other particles whose average grain size is smaller than that of brick sand, mixed into the layer of sand will fill the void spaces between the sand grains and thus destroy the sand's beneficial capillary effect. If this proves to be the case, it may occur over such an extended period of time that it will not be a problem since each exchange of crops in the bench would be accompanied by an application of clean sand. If it is found that the sand layer is rendered ineffective as a capillary medium it is possible that remedial measures may be found by which to renew the moisture-carrying effectiveness of the sand layer.

The structure of the bench soil should not be altered substantially nor should leaching of nutrients be excessive since there is no need for a surplus of water to stand on or percolate through the soil. Perhaps the greatest flood of water is applied when chemical fertilizers are washed into the soil by the usual means.

Probable Advantages of the Method:—The comparatively small investment and the resultant saving in the cost of watering are the more obvious advantages of this method. The low first cost is evident when it is considered that such a system may be installed in almost any existing bench including those on sloping ground and those obstructed by roof supports, water pipes or other obstacles. Moreover, a copper tube and sand layer irrigation system may be installed in rose benches at any time without removing and replacing the plants. In some cases the performance of other necessary tasks may prevent the grower from finding time to water the bench by hand at the particular time when the plants may most need water for their best production. By controlling a valve, the grower may dispense with one of his most time-consuming tasks and simultaneously maintain good production.

One of the cooperating growers states these additional reasons for his interest in the method. "With splashing of water on the foliage minimized, watering need not be confined to clear mornings; fertilizers are not washed to the center of the bench; leaching of nutrients is reduced considerably; packing of the soil and subsequent cultivation to induce absorption of water is practically eliminated. Tissue and branch injury as well as breakage by the hose is eliminated; dragging the hose is eliminated and dry walks are almost a possibility."

Other Applications:—As is indicated under the head of "Trials by Commercial Growers", this method of watering is not to be confined to the irrigation of benched rose crops in the greenhouse. The advantages of watering roses by this method or other crops which are to remain in benches for a period of years, are readily apparent, especially

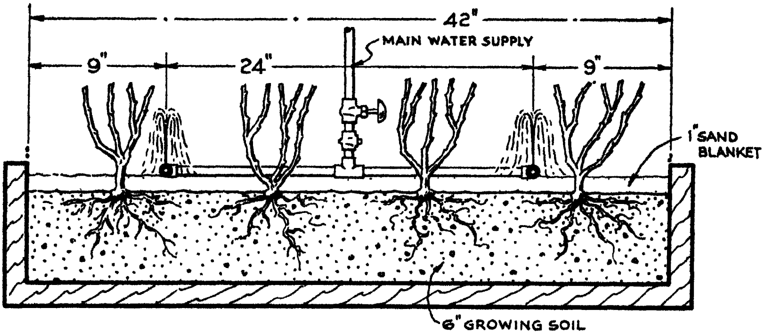

FIG. 2. Cross section of copper tube irrigation.

when it is considered that each change of plants is necessarily accompanied by a renewed or exchange layer of sand. Further experiments are being conducted with shorter-lived crops but to date there are insufficient cost data with which to form conclusions as to the saving of labor.

Another application is in propagation from cuttings. One commercial grower reports 100 per cent rooting of Geranium cuttings in a sand medium to which water was supplied by perforated copper tubes. Roots formed in 2 weeks and plants were potted in 3 weeks. The only shade provided was a light coat of whitening on the glass roof.

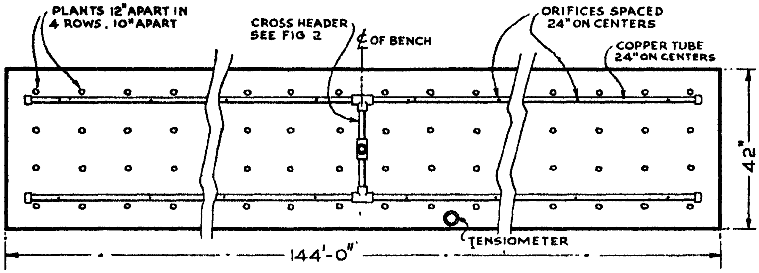
PLANTS 12" APART IN 4 ROWS, 10" APART
CROSS HEADER SEE FIG 2
℄ OF BENCH
ORIFICES SPACED 24" ON CENTERS
COPPER TUBE 24" ON CENTERS
42"
TENSIOMETER
144'-0"

FIG. 3. Surface view of copper tube irrigation.

An out-of-door application includes the successful propagation of woody plants by inserting softwood cuttings in sand and sand and peat rooting media. The bed was protected by a lath shade and water supplied daily through a grid of perforated copper tubes.

Cloth house and outdoor grown chrysanthemums have likewise been successfully irrigated by a similar means with a resultant increase in growth.

Outdoor grown roses have responded favorably in growth and bloom when irrigated through perforated copper tubes.

Experiments are now being conducted for the purpose of watering potted plants by plunging the pots in brick sand and supplying water to the sand through perforated copper tubes.

SUMMARY

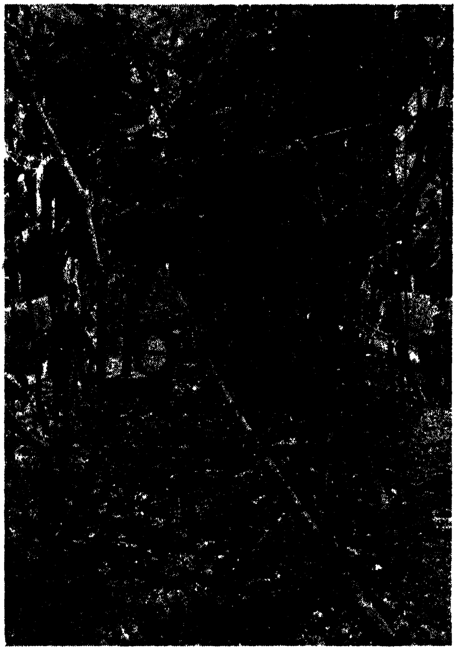

FIG. 4. Tube and tensiometer for complete surface pipe automatic watering.

Copper tube surface automatic watering has been found to be practical by commercial rose growers (Fig. 2–5). Success in irrigation by this method requires:

A 1-inch layer of brick sand on the surface of the soil.

Two lines of perforated tubes on benches not more than 48 inches wide.

Orifices spaced every 24 inches throughout the length of each line.

Orifices drilled .039 inches in diameter and on top of the tubes.

A screen placed in the water supply line to remove particles which might plug the orifices. (A tap on the tube with

FIG. 5. Check valve and solenoid connected to tube and operated by the tensiometer.

a hard object usually clears a stopped orifice).

The point of injection in the middle of the lines of tubes on level benches, in the high ends of tubes on sloping benches.

Copper tube in hard straight 12-foot lengths to facilitate handling and installation and alignment of orifices.

Three lengths of 3/8-inch Type L drilled copper tube on the last 36 feet of line.

Not more than 64 feet of 1/2-inch Type L drilled copper tube between the point of injection and 3/8-inch tube referred to above.

Tubes coupled together with 4-inch lengths of rubber tubing.

Ends of lines stoppered.

A gate or solenoid valve (1) to start or stop flow of water in the system.

An adjusting cock to regulate the water pressure.

A water pressure to permit the water to rise 4 to 8 inches above the tubes.

A tensiometer located near the side of the bench and equidistant between two consecutive orifices.

Water to be turned on when the tensiometer indicates 3 inches of tension and to be turned off when the tension recedes to less than 3 inches of tension. The control may be completely automatic (Fig. 4 & 5).

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Response of China Aster to Method of Daylength Extension[1]

By ALICE P. WITHROW, *Purdue University, Lafayette, Ind.*

RECENT work by Stuart (5) on a number of varieties of the short day plant, chrysanthemum, has indicated that desirable results in growth and delay in flowering in the fall and winter can be obtained by interrupting the night with a short period of irradiation around midnight. Long day plants of commercial flowering varieties have not been forced in a similar manner. However, the effects of short, more closely spaced periods of intermittent irradiation during the night have been reported for larkspur, annual chrysanthemum, stock, and China aster (3, 4, 7). Hume found (3), for instance, that China aster, variety Ball's White, under irradiances of from 10 to 35 footcandles (fc), flowered as readily under intermittent irradiation, when the lamps were on only 13.7 per cent of the time, with an on period of 1 second to an off period of 6.3 seconds, as under continuous radiation of the same irradiance. Using lower irradiances, varying from 0.75 fc to 8 fc over the bench, he found that a 5-hour irradiation treatment with the lamps on one-third of the time, using a 90 second period, gave as early flowering with Ball's Purple and Ball's Shell Pink aster as when the same irradiance was used continuously. He concludes that, under these conditions, intermittent irradiation makes possible considerable savings in electrical power. Other work by Withrow and Withrow (7) has indicated that for spinach and Biloxi soybean, continuous irradiation is more efficient in producing the long day response than is intermittent irradiation, providing the irradiance used in the continuous treatment is close to the minimum necessary to secure the long day flowering or vegetative response. In this case, the same total energies were used, regardless of the method of application.

The purpose of the experiment to be described was to observe the results to be obtained with different methods of application of supplemental artificial radiant energy on the daylength response of China aster, variety Heart of France.

PROCEDURE

China aster, variety Heart of France, was seeded on September 10 in sand-peat flats and was transplanted at 8- by 9-inch spacing to subirrigation gravel beds. A double concentration of Purdue F—Modified nutrient solution was used (8). Beginning on November 15 and continuing to harvest, the plants were given the radiation treatments indicated below, with the same total energy supplied in all cases, except where noted. Thirty plants were included in each treatment.

This variety of China aster has been shown to give the long day response to relatively low irradiances of 0.3 to 1 fc (6, 7); therefore the supplemental energy for the longest period of continuous irradiation was set at 0.5 fc since, at equal total energies, the irradiance would be at the lowest value in this treatment. The radiation treat-

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[1] Purdue University Agricultural Experiment Station Journal Paper No. 285.

ments included: (a) 0.5 fc for 12 hours; (b) 1 fc for 6 hours; (c) 2 fc for 6 hours, applied intermittently, the lamps on for 60 seconds and off for 60 seconds (receiving twice the irradiance as (b), but the same total energy of 6 footcandle hours); (d) 1 fc for 6 hours, applied intermittently (receiving the same irradiance as (b), but only half the total energy since the lamps were on only half the time); and (e) 6 fc for 1 hour from 12 m to 1 a. m. In all except the last, the lamps were turned on at 7 p. m. each night, the operation controlled by electric time switches. Incandescent lamps of the silverneck internal reflector type were used in two rows running the length of the bench to ensure even irradiance over the plants. The irradiances given above are those initially received by the plants. The plants in the individual treatments were separated by opaque black curtains, which were put in place in the evening and removed in the morning. A group of plants receiving the natural daylength was included as a control.

The temperature was maintained manually at 60 to 65 degrees F during the day and 50 to 55 degrees F during the night after October 15. Previous to this, the temperatures were higher. At temperatures of 55 degrees F and below, this variety of aster behaves as a long day plant (1, 2).

RESULTS AND DISCUSSION

The results obtained are shown in Table I and Figs. 1 and 2. The plants given 12 and 6 hours of supplemental radiant energy all had open flowers by March 1, whether the energy was applied continuously or intermittently. Those receiving 0.5 fc continuously for 12 hours each night produced more flowers per plant; the flowers were of excellent quality on straight stems with few laterals; and there were few singles. Some of the flowers were slow to open, however, and the harvest period extended over 4 weeks. The plants given 6 hours of supplemental continuous irradiation produced about the same quality flowers, although the average production was not so high as in the 12-hour condition. The harvest period lasted only 3 weeks. The plants given 2 fc intermittently for 6 hours were very similar in flower quality and production to the 6-hour continuous treatment receiving the same total energy. The flowers were a fraction smaller and the number of lateral buds formed were greater in number.

TABLE I—EFFECT OF CONTINUOUS AND INTERMITTENT RADIATION ON THE FLOWERING OF CHINA ASTER, VARIETY HEART OF FRANCE

Radiation Treatment	Total Energy (Foot-candle Hours)	Average No. Flowers	Average No. Buds	Average Flower Diameter (Cm)	Average No. Single Flowers	Average Stem Length (Cm)
0.5 fc, 12 hours.......	6	12.0	0.4	6.6	0.5	30
1 fc, 6 hours	6	10.4	0.7	6.5	1.5	28
2 fc, 6 hours, intermittent	6	10.7	3.3	6.3	0.5	31
1 fc, 6 hours, intermittent	3	10.0	6.6	6 1	0.6	27
6 fc, 1 hour.	6	9.5	14.0	5.5	0.2	35
Short day	–	9.1	20.1	4.8	3.3	23

The plants given the intermittent treatment at 1 fc started to flower

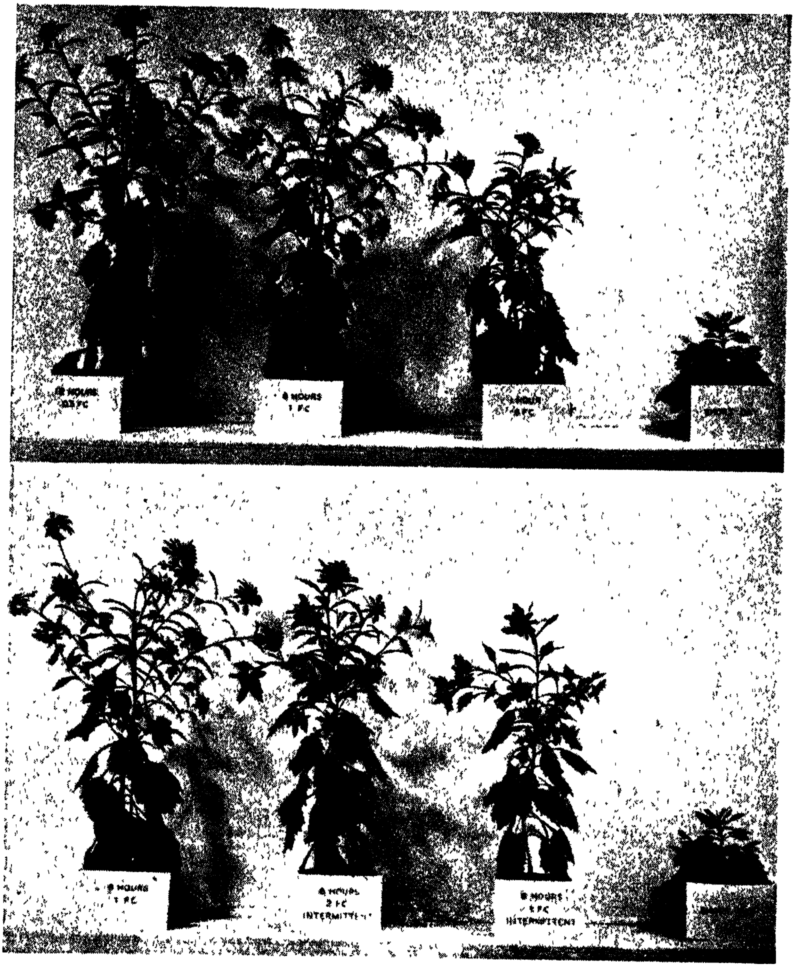

FIG. 1. Effect of various methods of applying supplemental artificial radiation on the flowering response of China aster, variety Heart of France.

on March 1, as did those under the three previously discussed treatments, but the flowers were slow in opening and harvesting took place over a 5-week period. There were about twice as many lateral buds as in the 2 fc intermittent treatment and the production was about 16 per cent less than that secured in the 12-hour treatment.

The plants irradiated for 1 hour each night with the same total energy as in the other treatments (except the 1 fc intermittent) came into flower at the same time as the control plants, about 10 days later than the plants in the other radiation treatments. There were fewer and smaller flowers than with the previously discussed treatments, with a large number of laterals. However, the stems were longer than

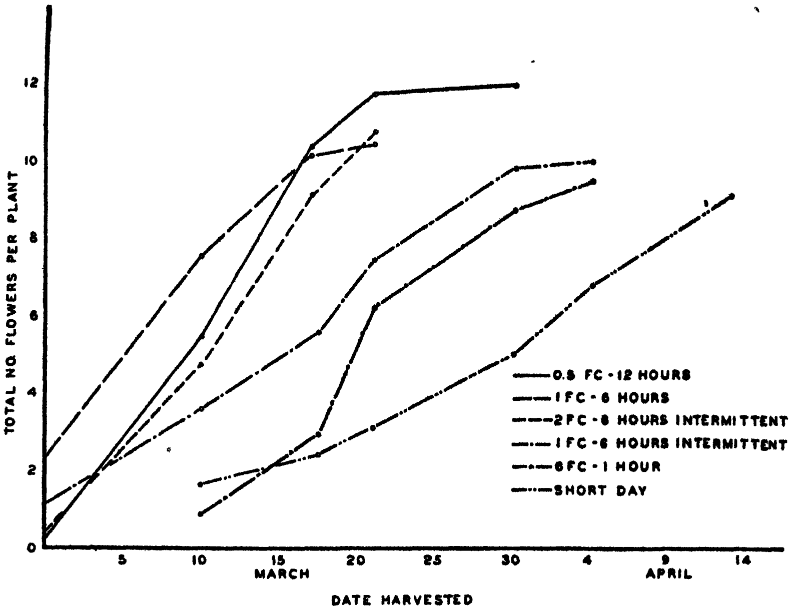

FIG. 2. Cumulative average flowering response of China aster, variety Heart of France, to various methods of applying supplemental artificial radiation.

those of the other plants and the flowers were salable. The harvest was over a 4-week period.

About one-third of the flowers from the control plants were single and practically all had curled petals and were abnormal in shape, as has been described previously for this variety of aster when grown under short days, at a night temperature permitting flowering (1). They were small, on short stems, with a very large number of laterals. They definitely were not salable.

The daylength was too long and the prevalent night temperatures too high in the early stages of growth to permit clear cut differences in the flowering time of the irradiated and control plants with this variety of China aster (2). However, the differences in flower quality and type of plant were very marked (Fig. 1).

SUMMARY

When used to supplement short winter days, equal total radiant energies from incandescent sources vary in effectiveness in hastening the flowering of Heart of France China aster, according to the method of application. Under the conditions of the present experiment, with low irradiances equivalent to 6 footcandle hours, optimum flowering occurred with a 12-hour period of supplemental radiant energy applied continuously. Almost as effective was the same energy applied for 6 hours. Little difference in results was obtained between 6-hour treatments with continuous and intermittent irradiation at the same total energy. However, at the same irradiance, the continuous method was more effective in bringing about the long day response. Interrupting the dark period with 1 hour of irradiation around midnight produced a marked effect on the stem length and flower form, but failed to decrease the number of days required for flowering to occur as compared with natural daylength.

For many varieties of China aster, the maximum long day response is secured at relatively low values of continuous irradiation of 1 or 2 fc or less. It therefore appears likely that the explanation of lack of correlation between previous results in studies of intermittent and continuous irradiation may be due to the high values of irradiance employed in some cases. Where the energy is added in excess of that necessary to secure the approximate maximum in long day response, the differences in efficiency between continuous and intermittent application would likely be masked and become apparent only when the radiant energy value is just sufficient to bring about the long day response in the continuous treatment.

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Some Results of the Effect of Controlled Humidity, Mediums, and Watering Methods on the Rooting of Cuttings of Some Deciduous and Evergreen Plants

By Rayford Houston and L. C. Chadwick, *Ohio State University, Columbus, Ohio*

Much earlier work has been done by Chadwick (1), Esper (2), Hitchcock (6), and others on the kinds of rooting mediums, particularly sand and peat and mixtures of the two. Little data has been presented recently on other materials of use in the rooting of deciduous and evergreen cuttings. Stoutemyer (9) has recently reported on the use of vermiculite as a rooting medium. The work reported here is concerned with studies of controlled humidity, rooting mediums, and various watering methods in the propagation by cuttings. This report represents some of the experimental work conducted during the past 2 years by the Horticulture Department at the Ohio State University.

MATERIALS AND METHODS

Many systems of humidification have been reported by such investigators as Raines (7), Gardener (4), Fisher (3), Stoutemyer (8), and Gossard (5). The type used for these experiments was a system making use of compressed air and Binks nozzles. Although this system is somewhat costly to install and considerable maintainance is required to keep the nozzles in operating condition when dirty or hard water is used, it is a very satisfactory mechanical system. The operating principle of the Binks system is merely the passing of a stream of compressed air over a column of water, which sucks up the water and distributes it in the form of a very fine mist from the nozzle. Number 164 Binks nozzles are used with this system.

A half-inch pipe is used to pipe the compressed air from the air compressor to each nozzle. For a propagating house 100 feet by 10 feet (two benches), place the nozzles 15 feet apart. The half-inch pipe line used to conduct the water to the nozzles should be placed directly parallel to the compressed air line and about 15 inches below it. The air line can be joined to the nozzle by means of a half-inch tee and a ¼-inch by ½-inch bushing. The water line can be connected to the nozzle by using two ⅜-inch by 6-inch pipe nipples and a ⅜-inch union or a short length of rubber hose can be wired to short pipe nipples in place of the union. It is necessary to have a small tank with a float valve to maintain a constant water level in the water line. The water in the water line must not be under pressure and should be so regulated that it stands in the pipe nipples about 3 inches below the nozzle. The entire system can be made automatic by the installation of an automatic value on the air line which is controlled by a humidistat. The water line should be flushed out regularly by attaching a hose to the water line and forcing water through the nozzles. The arrangement of the tank, air, water lines, and so on, is shown in Fig. 1.

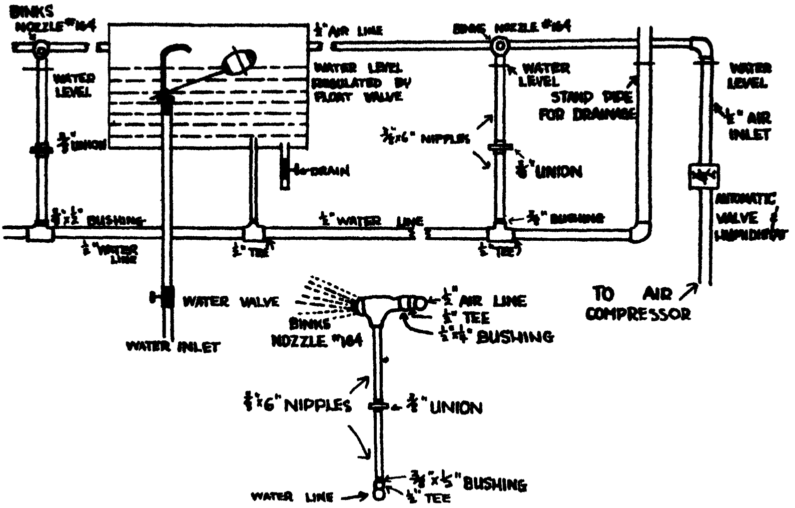

FIG. 1. Diagram of the Binks system of humidification.

The placement of the nozzles should be above the plants near the glass so that the mist can be directed at a slight downward angle on the plants. The air compressor used should be capable of maintaining at least 40 to 50 pounds of pressure in the air line when all the nozzles are operating.

The methods of watering used were manual subirrigation, automatic constant level subirrigation, and overhead. Manual subirrigation is performed by attaching a short length of rubber hose (female connections on each end) to a pipe running into the bottom and center of the bench. A watering hose is then attached to the short hose connection and the water turned on. When the water has reached the surface of the rooting mediums, it is turned off and the hose disconnected, allowing the water to drain out. The automatic constant level system is constructed by a pipe running from a small tank or 8-inch flower pan located at the end of the bench, to the bottom and center of the bench. The level of the water in the propagating bench is regulated by a float valve in the tank or flower pan. Benches for the subirrigated plots were constructed of metal (galvanized sheet iron, 29 gauge) and have V-type bottoms. In these tests, the water level was maintained ¼ inch above the gravel filling the V bottom of the bench. Approximately 4 inches of the rooting mediums were used.

Cuttings were made in the usual manner with the basal cut being made slightly less than ½ inch below the node. All cuttings were treated with Rootone with the exception of the *Ilex opaca* cuttings. The cutting of *Ilex opaca* were treated with Hormodin No. 3. The cuttings were first dipped in water, shaken to remove the excess, and then dipped into the dust.

The cuttings were placed in lots of 25 or 50 in both a north lean-to and a south lean-to propagating house. During the winter, the benches in the north lean-to were provided with hot water heat and supplemented with electric cables. The benches in the south lean-to were provided with hot water pipes placed under the benches for bottom heat. A medium temperature of about 70 degrees F, and a house temperature of approximately 5 to 10 degrees F lower than the medium temperature was maintained. No bottom heat was used during the summer months. A moderate amount of shading was used on the glass during the summer months.

SOFTWOOD CUTTINGS OF GREENHOUSE ROSES

Partially trimmed and untrimmed three-eye Better Times rose cuttings were used in this experiment. Fifty cuttings were placed in each plot in the south lean-to propagating house in medium silica sand (grade No. 7) and coarse silica sand (grade No. 5). The three watering methods, manual subirrigation, automatic constant level subirrigation, and overhead were used. The manual subirrigated plots were watered once daily. The south lean-to propagating house was divided into two sections. One section was provided with a constant humidity of 70 per cent and the other at 60 per cent constant humidity. The humidistat controlled Binks system of humidification was used to regulate the humidity of the sections. The cuttings were treated with Rootone and placed in the benches October 17, 1945, and removed November 17, 1945. The best results were obtained with partially defoliated cuttings in the overhead watered, medium silica sand plot. This plot was in the section of the propagating house where the humidity was held constantly at 70 per cent. This test was later repeated and the results are shown in Table I.

In another experiment, cuttings of the Better Times rose were placed in the north lean-to propagating house on November 15, 1945, and removed 4 weeks later. All cuttings were watered overhead. Three plots were used: steam sterilized medium fine bank sand, bank sand

TABLE I—EFFECT OF CONSTANT HUMIDITY AND METHOD OF WATERING ON THE ROOTING OF CUTTINGS OF BETTER TIMES ROSES IN SILICA SAND (GRADE NO. 7)*

Treatment	Percentage Rooted			Percentage Unrooted or Dead	
	Good Roots**	Poor Roots†	Total	Alive, Unrooted	Dead
70 Per Cent Constant Humidity					
Overhead watered	60	36	96	—	4
Constant level subirrigation	—	12	12	24	64
Manual subirrigation	12	36	48	24	28
60 Per Cent Constant Humidity					
Overhead watered	60	20	80	4	16
Constant level subirrigation	—	12	12	8	80
Manual subirrigation	20	64	84	12	4

*Cuttings taken November 11, 1945; data recorded December 15, 1945; 25 cuttings per plot.
**Good roots—cuttings having many strong, sturdy roots.
†Poor roots—cuttings having few, weak roots.

with ½ ounce fermate per square foot, and medium fine bank sand with 1 ounce fermate per square foot. The steam sterilized medium fine bank sand gave the highest rooting percentage. Fermate dusted evenly over the surface of the sand and then watered in prior to sticking the cuttings seemed to have an inhibiting effect on the elongation of the roots. The roots formed were much shorter but somewhat larger than those from the steam sterilized medium fine sand plot.

Cuttings of Taxus Cuspidata

Cuttings of *Taxus cuspidata* were placed in the south lean-to propagating house on January 10, 1946, and the rooting data was recorded on March 22, 1946. The methods of watering used were manual hand subirrigation, constant level or automatic subirrigation, and overhead. The rooting medium used was silica sand (grade No. 7). Two houses were used in the experiment. The humidity of one house was held at 70 per cent and the other at 60 per cent. Twenty-five cuttings were used per plot.

From the results recorded (Table II), there was little difference in percentage of rooting between the overhead and manual hand subirrigation plots in either the 70 per cent or 60 per cent humidities. The automatic, constant level subirrigation gave very poor rooting percentage in this experiment. It is believed that the level of the water, which was set ¼ inch above the gravel in the bottom of the bench below the rooting mediums, may have been too high.

TABLE II—Effect of Constant Humidity and Method of Watering on the Rooting of Cuttings of Taxus Cuspidata in Silica Sand (Grade No. 7)*

Treatment	Percentage Rooted			Percentage Unrooted or Dead	
	Good Roots**	Poor Roots†	Total	Alive, Unrooted	Dead
Humidity 70 Per Cent					
Manual subirrigation	80	8	88	12	—
Constant level subirrigation	40	20	60	28	12
Overhead watered	88	8	96	4	—
Humidity 60 Per Cent					
Manual subirrigation	76	20	96	4	—
Constant level subirrigation	20	52	72	24	4
Overhead watered	80	16	96	4	—

*Cuttings taken Jan 10, 1946; Data recorded Mar 22, 1946; 25 cuttings per plot.
**Good roots—Cuttings having many strong-sturdy roots.
†Poor roots—Cuttings having few, weak roots.

Softwood Cuttings of Deciduous and Evergreen Plants

Tests were made with softwood cuttings of deciduous and evergreen plants during the summer of 1946. From 15 to 100 cuttings were used per plot, depending upon the availability of material. The results are reported in Table III. Humidity of the south lean-to was maintained at 75 per cent and the cuttings were watered by the overhead, hand subirrigated, and constant level subirrigated methods. The rooting mediums used were medium silica sand (grade No. 7), coarse silica sand (grade No. 5), and medium vermiculite (grade No. 2).

TABLE III—EFFECT OF TYPES OF MEDIUMS AND WATERING METHODS ON THE ROOTING OF SOFTWOOD CUTTINGS OF SOME DECIDUOUS AND EVERGREEN PLANTS

Plants and Time in Bench	No. of Cuttings Per Plot	Percentage Rooting					
		Method of Watering			Type of Medium		
		Manual Subirrigation	Constant Level Subirrigation	Overhead Watering	Silica Sand (No. 7)	Silica Sand (No. 5)	Medium Vermiculite (No. 2)
Acer palmatum (Aug 19 to Oct 7)	20	15	—	40	15	40	20
Actinidia arguta (Jul 2 to Aug 16)	75	—	—	82	73	—	82
Berberis thunbergi compacta (Aug 24 to Oct 1)	15	—	—	90	53	3	90
Cotoneaster bullata (Jul 2 to Oct 4)	25	80	76	—	—	—	80
Daphne, Summerset (Jun 1 to Jul 25)	25	80	80	92	88	92	80
Fontanesia fortunei (Jul 2 to Aug 10)	25	72	88	64	64	—	88
Hydrangea petiolaris (May 24 to Dec 10)	33	—	—	48	3	—	15
Ilex opaca (Jul 26 to Sep 25)	15	67	55	80	67	55	80
Leucothoe catesbaei (Aug 27 to Oct 18)	15	—	—	78	—	60	93
Lonicera korolkowi zabeli (Apr 24 to Jun 9)	15	40	33	73	33	40	73
Malus baccata mandshurica (Aug 3 to Sep 27)	20	10	60	30	30	10	60
Styrax japonica (Jul 2 to Aug 10)	25	80	68	80	80	—	80
Syringa henryi lutèce (Apr 24 to Aug 10)	20	95	80	100	95	80	100
Syringa oblata (Apr 19 to Jun 8)	15	20	58	29	29	20	58
Syringa villosa (May 22 to Jul 1)	25	96	86	100	96	88	100
Viburnum burkwoodi (Jul 2 to Aug 10)	100	—	—	97	—	—	97
Viburnum fragans (Jul 2 to Aug 12)	25	96	92	100	96	—	100
Viburnum pubescens canbyi (Jul 2 to Aug 10)	88	—	—	94	61	—	94
Viburnum rhytidophylloides (Jun 29 to Aug 10)	15	100	93	86	93	86	100
Viburnum sargenti (Jul 15 to Aug 15)	32	72	28	—	72	—	—

Of the three watering treatments used, the overhead method gave the best rooting percentage with the majority of the cuttings. The automatic constant level subirrigation method gave the poorest rooting in most cases. The results also show that medium vermiculite (grade No. 2) gave the highest rooting percentage in most cases. In these tests silica sand (grade No. 7) gave slightly less rooting percentage, with silica sand (grade No. 5) giving the poorest rooting percentage with many of the different kinds of cuttings.

SUMMARY

In these tests where overhead, hand subirrigation, and constant level subirrigation methods of watering were used, the best results with Better Times rose cuttings were obtained with the overhead watering method. The automatic constant level subirrigation method is worthy of further investigation but it is necessary to maintain careful regulation of the moisture level. This will need to be varied with different rooting mediums. The manual subirrigation method appeared to be more satisfactory than the automatic constant level subirrigation. The frequency of watering will need to be varied with the time of year, type of rooting medium, and the kind of cuttings handled.

Better Times rose cuttings showed a higher percentage of rooting in the steam sterilized bank sand than in the plots containing fermate-treated bank sand. Fermate appeared to have an inhibiting effect on the elongation of roots. A constant humidity of 70 per cent appeared to be more favorable with Better Times rose cuttings than a humidity of 60 per cent.

With *Taxus cuspidata* cuttings, there seemed to be little difference in the rooting percentage between cuttings placed in plots watered overhead and those placed in the manually subirrigated plots. There was some rotting of the basal ends of the cuttings placed in the automatic constant level subirrigated plots. A constant humidity of 60 per cent appeared to be as satisfactory as 70 per cent for cuttings handled in propagating houses during the winter. Medium silica sand (grade No. 7) appears to be a favorable rooting medium.

The overhead method of watering appeared to be the most satisfactory of the methods used for the rooting of softwood cuttings of deciduous and evergreen plants handled in a propagating house during the summer. The manual subirrigation method was quite favorable, but the rooting percentages were not as high. The automatic constant level subirrigation method gave the lowest percentage of rooting. The best type of rooting medium will vary according to the plant type. Controlled humidity of 75 per cent appears to be satisfactory for the rooting of softwood cuttings in propagating houses during the summer. With humidity held at this percentage, propagating houses may be used as readily and as successfully for rooting softwood cuttings as hot beds or cold frames.

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Year-Around Chrysanthemum Production

By Kenneth Post, *Cornell University, Ithaca, N. Y.*

Normally a variety of chrysanthemum blooms within 10 days of the same date each year. The use of black cloth to reduce the length of day (1) has enabled growers to flower chrysanthemums starting during June and continuing to the normal time of bloom for the variety. The use of artificial light to lengthen the day and prevent flower bud formation, thus delaying flowering, was possible when the approximate date at which bud formation started was determined (2). If flower buds were prevented from forming at normal season (August 15 to 30) and this delay continued more than one month, few or no buds formed. This lack of bud formation during the winter months was overcome by maintaining a minimum night temperature of 60 degrees F (3).

The 60-degree minimum temperature during the bud forming period, the use of black cloth to reduce the length of day and cause flower buds to form in normal long days, and the use of artificial light to lengthen the day and prevent flower buds from forming during the normal short days of winter, thus promoting vegetative growth, are the fundamentals for the program of year-around production of chrysanthemums.

From September 1 to March 25 the days are short enough to promote flower bud differentiation. Vegetative growth during this period is promoted by lengthening the day with electric lights. From April 20 to August 15 the plants should vegetate normally and form flower buds only when the length of day is reduced.

August 15 to September 1 and March 25 to April 20 are the periods in fall and spring when the days may or may not be short enough for flower bud initiation depending on variety and day length as affected by local obstructions and weather conditions. During these periods accurate control of budding is possible only by artificial means.

Starting in October of 1945 rooted cuttings[1] which had been subjected to long days while on the stock plants and in the rooting media were planted directly to soil in the greenhouse bench. A second planting was made in February and starting June 15 plantings were made each month. Twenty-six varieties including pompons, singles, anemones and large flowered disbudded types were used at each planting. Twenty plants of each variety were spaced 7½ by 8 inches, pinched after 15 days, given long days from planting time to 30 days after pinching, then short days for flowering. Fifty or more plants of each variety were planted 4 by 6 inches, not pinched and given 20 long days, then short days for flowering.

The plants which were pinched after 15 days required about 4 months from planting to cutting. When no pinch was given about 3 months were required for the crop.

The plants were surface watered at 1 inch of capillary tension (5).

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[1] Rooted cuttings were supplied by Yoder Brothers, Barberton, Ohio. Eight of the early varieties used in the first planting were supplied by Harry Allyn, Big Flats, New York.

Fertilizers were added to maintain nitrate above 15 parts per million, phosphorus above 5, potash above 20, tests according to Spurway (6), and a pH above 5.5. When artificial light was used the exposure was for 2 or more hours per night.

After the first two plantings it was obvious that the large flowered disbudded varieties would produce no more than 30 inches of stem when not pinched and given 20 long days after planting. This interval was increased to 25 long days and the stem length was increased to near 36 inches. To date it is evident that 30 to 35 days would be desirable for the vegetative period to obtain stems of sufficient length for marketing. Early varieties of pompon and similar types were also too short stemmed for commercial sale with 20 long days. It appears that 25 to 30 long days are desirable. Late varieties were, however, satisfactory with the 20 long-day interval.

Plants pinched after 15 days and given 30 more long days before the short-day treatment produced sufficient stem length in most treatments and on most varieties of pompons. Disbudded varieties did not produce sufficient stem length and should probably be given 35 to 40 long days after the pinch.

Bronze and pink varieties were unsatisfactory during the months including June to August because the color was lighter than normal. These varieties were also light colored from October to February at the 60 degree temperature. A few trials indicated this color improved by reducing temperature to 55 degrees after 1 month of short days to form flower buds. It is evident that the intensity of bronze and pink is associated with photosynthesis and respiration.

Varieties which flower normally before November 20 gave good quality flowers from July to October. From November to February these varieties often lacked substance and the central petals sometimes developed poorly in the head. To date these varieties have not been flowered from February to July.

Varieties which flower normally after November 20 have given excellent quality from September to April but have been difficult to flower with the available black cloth from May to August. These varieties apparently require a lower light intensity for bud formation or a shorter day.

The trials to date indicate that a shorter day is necessary for bud development than for bud initiation. From September 1 to near October 1 flower buds developed slower, with no artificial reduction of day length, than in November and later. They also developed at a slower rate than plants flowered in July and August by artificially reducing day length. Most of these plants produced crown buds (4) indicating that the days were short enough for bud formation but too long for the development.

To accurately control bud formation and development it now appears that day length should probably be reduced to near October 1 or until 1 month of artificial short days had been given. As an example, if short days were started August 15 they could be discontinued September 15. If started August 1 they could be discontinued September 1. As previously suggested (4), short-day treatments started earlier than August 1 can safely be discontinued only when color shows in the buds or September 1.

During the period from near March 1 to April 20 buds normally form but some varieties become vegetative and flower buds do not develop uniformly unless artificial short days are given.

SUMMARY

1. Chrysanthemums have been flowered each month of the year 1946 by controlled day length and at a minimum temperature of 60 degrees F.
2. The stock plants and cuttings were subjected to long days.
3. Rooted cuttings planted directly to the bench 4 by 6 inches were given 20 long days then short days for bud formation. This time was not long enough for proper stem length excepting for late varieties; 25 to 35 long days appear more satisfactory for proper stem length.
4. Rooted cuttings planted 7½ by 8 inches were given long days. The terminal growing point was removed after 15 days and the long-day treatment continued 30 days before reducing the day length for bud formation. The interval of 30 days gave sufficient stem length, except for large flowered disbudded varieties and early pompons, where 35 to 40 days appear more satisfactory.
5. Bronze and pink varieties were of poor color from June to August and from October to February.
6. Late varieties gave the best quality in winter and early varieties the best quality in summer.

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The Aggregation and Aeration of Some Greenhouse Soil Mixtures for Roses and Carnations

By. STEPHEN H. RAY and JAMES B. SHANKS, *Ohio Agricultural Experiment Station, Columbus, Ohio*

RESEARCH at the Ohio State University on greenhouse soils with particular reference to the physical conditions of soil used in production of roses and carnations has been carried on for the past three years. The problem has been that of estimating several of the soil properties, their determining factors, and subsequent effect on production. Soil properties investigated were aggregation, air space, and soil air composition. The factors affecting these soil properties which were studied were additions of both organic and inert materials, methods of water application, mulching materials, and mechanical modification.

METHODS

The degree of aggregation was estimated by the method of Yoder (6) using screens of 5, 2, 1, .5, and .25 millimeter openings which oscillated at the rate of 36 strokes per minute. Results were expressed as per cent of aggregation and average size of aggregates. The latter figure was derived by assuming the diameter of particles to be that of the screen on which they were retained.

The air space in a soil was assumed to correspond to the non-capillary porosity which was measured by the method described by Leamer and Shaw (4). The composition of the soil air was estimated by taking samples of the soil air drawn from permanent gas wells made from glass tubing similar to those used by Boynton and Reuther (1), collecting over an acidulated salt solution as used by Furr and Aldrich (2), and analyzing for carbon dioxide and oxygen with a Haldane (3) gas analyzer.

Porosity and aggregation analyses were run in triplicate on the average of every other month on plots averaging 40 square feet in size. Soil air samples were taken from two to five wells per plot depending on variations in results. Analyses were made as often as every 2 hours in determining the oxygen curve at watering time.

The method of Post and Seeley (5) was used in the automatic subirrigation method of watering. The ordinary method of subirrigation practiced was to force water through drain tile in the bottom of the greenhouse bench until the soil surface was flooded. In the constant level method of watering the water remained in the bottom of the bench at the level of the top of the coarse gravel which surrounded the drain tile and filled the bottom of the bench. There was soil to a depth of 5 inches on the top of the gravel.

Mechanical analyses of the soils used in the experiments gave the following average results: less than .005 millimeter — 30 per cent; .005 to .05 millimeter — 30 per cent; greater than .05 millimeter — 40 per cent. Sand used in soil mixtures was ordinary builders sand and the cinders used averaged $^1/_{16}$ to $^1/_4$ inches in diameter.

Experimental Results

1. Records of flowers produced by both roses and carnations were kept in all cases but in no case were there any significant differences in production under the treatments given.

2. Using five treatments, soil with one-third manure had the greatest aggregation from the third to the sixteenth month with a maximum of 91 per cent but at the end of 24 months had the least aggregation with 68 per cent. Soil with one-fourth manure was intermediate in amount of aggregation. Soils with one-third alfalfa hay or corn stover had the least aggregation until the sixteenth month with the one-third alfalfa soil having the greater aggregation of the two. A soil composed of the top 3 inches of a bluegrass sod was intermediate at first but after the sixteenth month had the greatest aggregation averaging 84 per cent at which time it also had the largest size of aggregates averaging three millimeters in diameter (Fig. 1).

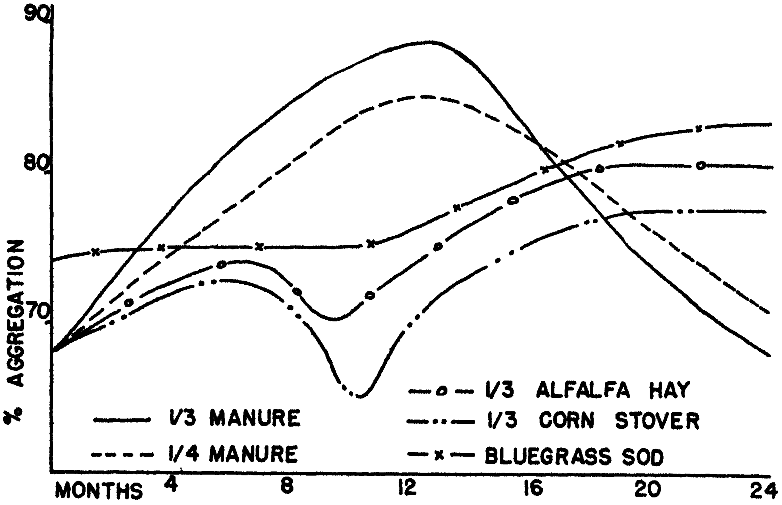

Fig. 1. Aggregation of a rose soil with different organic materials.

3. Where rose soil was "dug" or churned up with forceful streams of water both with and without manure there was little permanent change in the physical condition of the soil. The original soil in this experiment was highly aggregated.

4. Over the period of a year, manured soil which had been steam sterilized had a greater aggregation temporarily, but after 8 months the unsterilized soil was more highly aggregated. Unmanured soil showed a very slight increase in aggregation after sterilization over unmanured and unsterilized soil. At all times the unmanured soils had less aggregation than the manured soils (Fig. 2).

5. Duplicate plots of carnation soils were made up containing one-fourth manure and one-fourth cinders, one-fourth manure, one-fourth

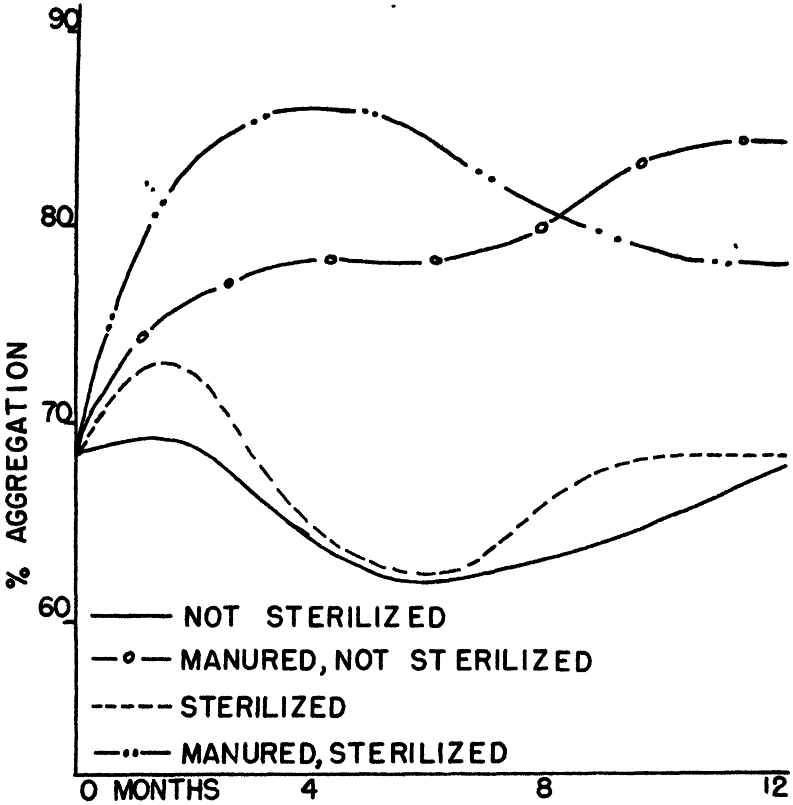

FIG. 2. Effect of steam sterilization and organic matter on the aggregation of a rose soil.

cinders, and soil with no additions. Soil with both cinders and manure had the greatest amount of air space for both replications over the 8 months period of the experiment. The soil with manure was second, soil with cinders was third, and soil with no additions had the least amount of air space. In general, the amount of air space declined over the 8 months period but the curves were somewhat parallel (Fig. 3). The aggregation was greatest in the plots containing manure. Manure and cinders were second, soil with no additions was third, and soil with cinders had the least aggregation (Fig. 4).

6. Rose soil with additions of sand or cinders had a slightly higher air space than soil without these additions. Soil with peat moss had a slightly higher air space than soil which had manure added.

7. At the end of a 10 months period the air space of rose soil without a mulch had declined 5 per cent below soil mulched with straw, manure, or peat moss. Soil with two applications of sucrose, broadcast at the rate of 16 pounds per 100 square feet, did not decline in air space. There were no significant differences in the aggregation of soil

mulched with straw, manure, or peat as compared with the no mulch plots although the soil to which sucrose had been applied had a much greater aggregation and larger aggregates. The increased aggregation lasted about 3 months after the application of sucrose. Water percolation in the soil to which sucrose had been applied, as well as in the mulched soils, was much better than in the bare soil.

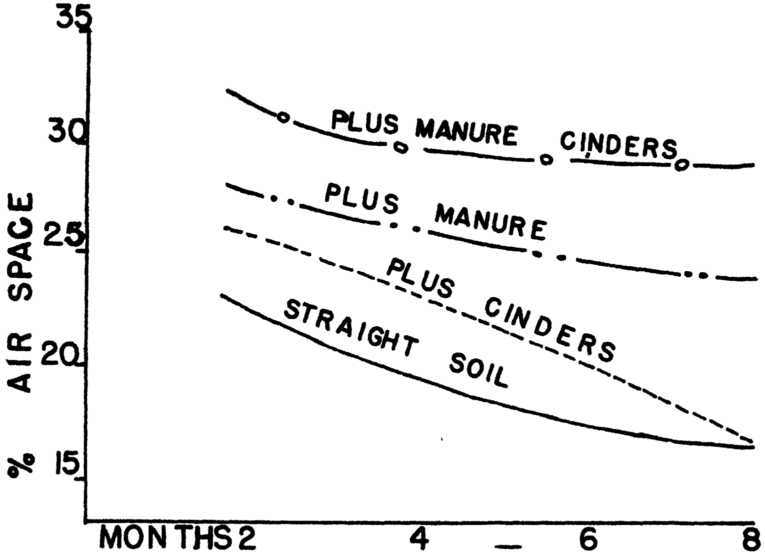

FIG. 3. Effect of additions of cinders and manure on the air space of a carnation soil.

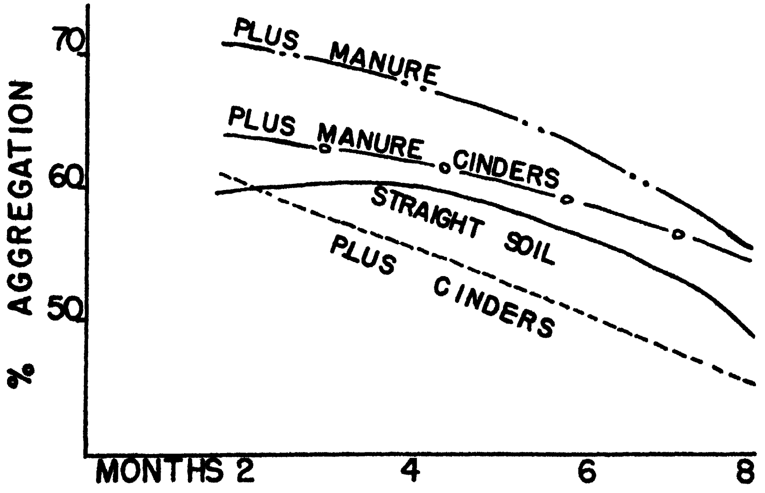

FIG. 4. Effect of additions of cinders and manure on aggregation of a carnation soil.

8. Using the same rose soil, three plots mulched with manure and three plots on which Chewings fescue had been grown between the plants were identical as to amount of air space and aggregation over a period of 18 months. In another experiment including bluegrass, the plot with bluegrass and the plot with fescue retained a greater air space at the end of 10 months than either manure mulch or no mulch plots. A soil in roses which had not been replanted for 7 years and in which the air space was very low and the aggregation very high had a 4 per cent increase in the soil air space at the end of 8 months after being seeded with fescue, as compared with the same soil mulched with manure. There was no difference in the soil aggregation under these two treatments at any time during the period.

9. At the end of 8 months the air space of a rose soil watered overhead at a tension of 3 inches of mercury was 31 per cent. Under the automatic subirrigation system of subirrigation with water added at a tension of 3 inches of mercury the same soil declined to 25 per cent air space, and under the constant level system of watering the air space declined to 19 per cent. The aggregation of these soils was in the same relative order. A soil watered by automatic subirrigation to which one-fourth sand had been added maintained 31 per cent air space (Fig. 5).

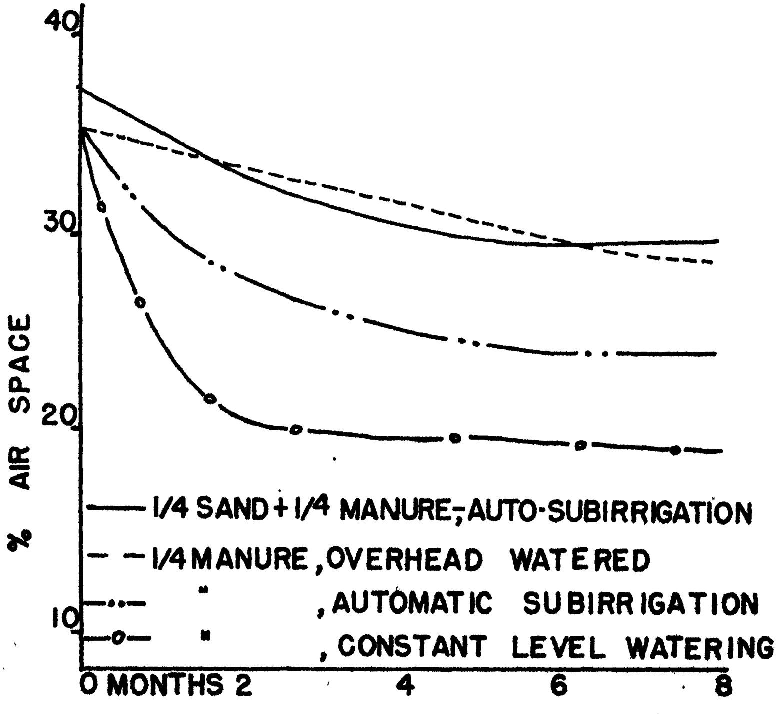

FIG. 5. Method of watering and the air space of a rose soil.

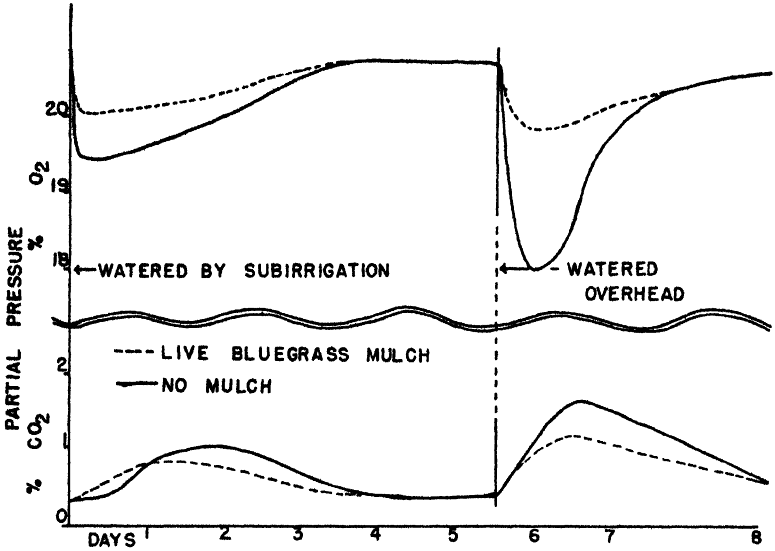

FIG 6 Effect of watering on the atmosphere of a rose soil

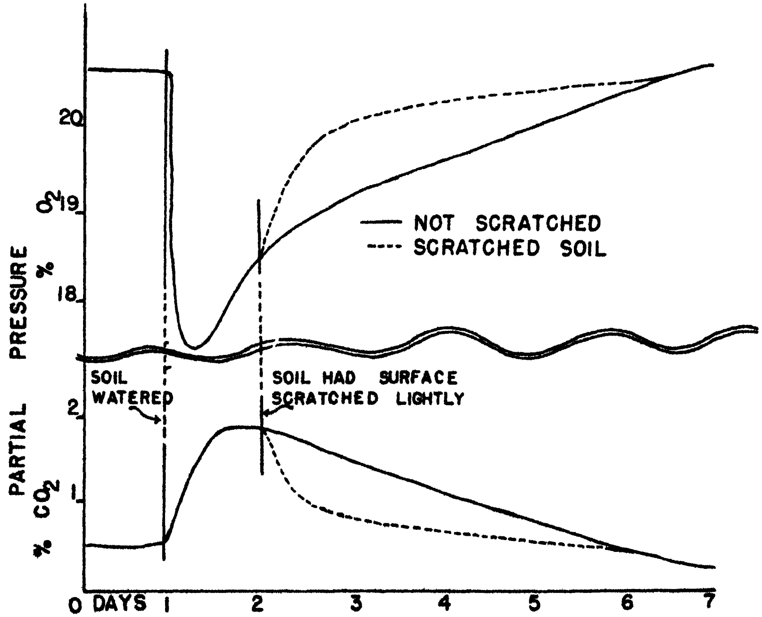

FIG 7 Effect of surface scratching on the atmosphere of a carnation soil after overhead watering.

10. Immediately after overhead watering there was a reduction in the partial pressure of the oxygen in the soil atmosphere which usually reached its lowest point in from 6 to 9 hours and which gradually increased to its highest point as the soil dried out. Dry soils averaged 20.5 per cent while partial pressures as low as 14 per cent were recorded soon after watering. The partial pressure of carbon dioxide increased gradually after overhead watering and reached its highest point in from 1 to 2 days and then gradually declined to its lowest point as the soil dried out. Dry soils averaged 0.3 per cent while partial pressures as high as 3 per cent were recorded after watering (Figs. 6 and 7).

11. Soil mulched with manure or bluegrass did not show so great a reduction in oxygen after overhead watering as did bare soil (Fig. 6). When the surface of the bare soil was scratched lightly soon after watering the oxygen content was higher than where the soil had not been scratched. This effect lasted only until the surface began to dry (Fig. 7). There was very little reduction in oxygen where there were numerous drainage openings in the bottom of the bench and under these conditions the absence or presence of a mulch had little or no effect on the oxygen content.

12. Where sucrose had been applied, the oxygen content of the soil was reduced considerably.

13. Soils watered by subirrigation did not have so great a reduction in oxygen as when the same soil was watered overhead (Fig. 6). Rose and carnation soils watered by the constant level method had an oxygen partial pressure in the soil atmosphere of approximately 19 per cent.

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Prepackaging of Cut Flowers

By ANDREW HAUGE, WILLARD BRYANT, and ALEX LAURIE,
Ohio State University, Columbus, Ohio

RESEARCH work has been conducted at the Ohio State University for the past 2 years to investigate various methods of handling of cut flowers and the effects of these different treatments upon the salability and the keeping quality of cut flowers. The most promising results, to date, have been obtained by packaging cut flowers in a cellophane enclosed container. This method not only facilitates the handling of cut flowers, but has in most cases resulted in superior keeping qualities. Presented herein is a summary of work done and the results obtained.

In the discussion that follows, all flowers described as "packaged" were treated as follows: the bottoms of ordinary retail flower boxes of varying sizes (roses, 1¾ x 5 x 18 inches; carnations, 3 x 5 x 18 inches; chrysanthemums, 5 x 8 x 28 inches) were used as containers. These boxes were coated inside and out with paraffin to lessen the absorption of moisture of the enclosed atmosphere by the box. This was found to be an essential step in order to prevent the loss of excessive amounts of moisture by the plant tissues during the storage period. Cut flowers were then placed in the containers and then enclosed in a gas impervious cellophane bag (DuPont's heat-sealing cellophane, 300 M.S.A.T. 86). The open end of the cellophane bag was then folded together and sealed by passing a hot sealing iron over this surface. The process described here can be accomplished on a large scale by mechanical packaging machines.

I. Roses. The tests conducted on roses were divided into the following treatments:

1. *Packaged Direct:*—After cutting and grading, the roses were packaged immediately and then placed in refrigerated storage, at 40 to 45 degrees F. Under this treatment, the rose stems are not in contact with water until removed from storage.
2. *Water 1 Hour:*—After cutting and grading, the roses were placed in water in the refrigerator at 40 to 45 degrees F for 1 hour, and then packaged and returned to the refrigerator.
3. *Water 6 Hours:*—After cutting and grading the roses were placed in water in the refrigerator at 40 to 45 degrees F for 6 hours and then packaged and returned to the refrigerator.
4. *Water 10 Hours:*—After cutting and grading, the roses were placed in water in the refrigerator at 40 to 45 degrees F for 10 hours, and then packaged and returned to the refrigerator.
5. *Water 24 Hours:*—After cutting and grading, roses were placed in water in the refrigerator at 40 to 45 degrees F for 24 hours and then packaged and returned to the refrigerator.
6. *Check:*—After cutting and grading, roses were rolled in a spiral wrap using parchment paper and placed in water in the refrigerator at 40 to 45 degrees F. This is the common commercial method used among rose growers at present.

At the time of packaging, all roses were misted lightly with water to increase the humidity within the package. All storage temperatures were maintained between 40 to 45 degrees F. The above series of treatments were prepared daily for 7 days using the variety Better Times. On the 8th day all treatments were removed from the refrigerator. The basal ends of the stems were recut and the roses placed in vases of water at room temperature (approximately 70 to 75 degrees F).

TABLE I—ACCEPTABILITY OF CUT ROSES AT ROOM TEMPERATURE AFTER 5-DAY STORAGE WITH VARIOUS STORAGE TREATMENTS

Treatment	Time at Room Temperature					
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days
Packaged direct	Good*	Good	Good	Fair**	Fair	Poor†
Water 1 hour, packaged	Good	Good	Good	Fair	Fair	Poor
Water 6 hours, packaged	Good	Good	Good	Fair	Fair	Poor
Water 10 hours, packaged	Good	Good	Good	Fair	Fair	Poor
Water 24 hours, packaged	Good	Good	Fair	Fair	Poor	——
Check	Good	Good	Fair	Poor	——	——

*Good—Roses less than three-quarters open, flower color good, and petals and foliage turgid.

**Fair—Roses three-quarters to fully open, flower color no longer true or bluish pigments visible and substance of petals and foliage good.

†Poor—Roses fully open. Noticeable fading of color or heavy blue cast present. Substance poor with or without leaf drop.

The time period between bud stage and fully open flowers as shown in Fig. 1 will vary according to environmental conditions to which roses are subjected when placed in water after storage. The relative rates of opening, however, will be as indicated above.

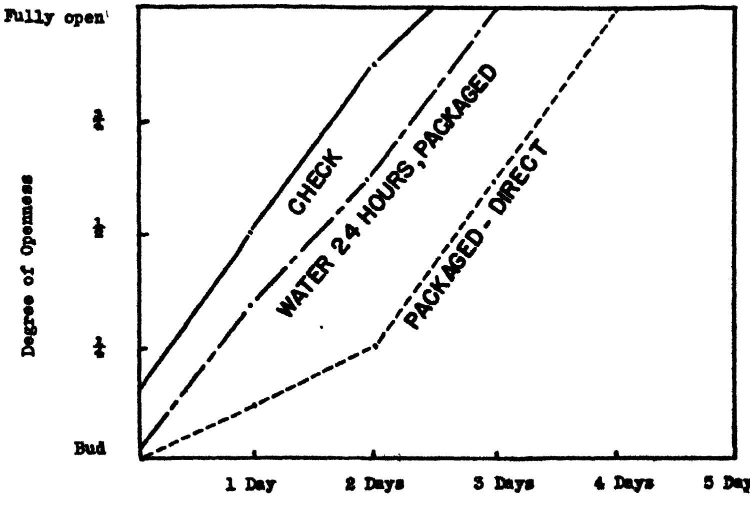

FIG. 1. Relative rate of opening of cut roses after 5 days storage (when placed in water at room temperature).

Roses packaged direct when stored for periods of 5 days or less, are in a tighter bud stage when removed from storage as compared to the check treatments. They open more slowly and retain their color longer, usually requiring from 3 to 4 days to reach the fully open stage.

Roses placed in water for 24 hours and then packaged showed a tendency to be more open than those packaged direct when placed at room temperature, in general losing color and reaching the fully open flower stage from 24 to 48 hours earlier than the latter.

Roses placed in water for a period of 1 to 10 hours and then packaged gave almost as satisfactory results as those packaged direct.

TABLE II—ACCEPTABILITY OF CUT ROSES AT ROOM TEMPERATURES WHEN PACKAGED DIRECT AND STORED FOR VARYING PERIODS OF TIME

Storage Period (Days)	Time at Room Temperature					
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days
8	Fair**	Fair	Poor†	——	——	——
7	Good*	Fair	Fair	Poor	——	——
5	Good	Good	Good	Fair	Fair	Poor
3	Good	Good	Good	Fair	Fair	Poor
1	Good	Good	Good	Fair	Fair	Poor

*Good—Roses less than three-quarters open, flower color good and petals and foliage turgid.

**Fair—Roses three-quarters to fully open, flower color no longer true or bluish pigment visible with substance of petals and foliage good.

†Poor—Roses fully open. Noticeable fading of color or heavy blue cast present. Substance poor with or without leaf drop.

The most consistent and satisfactory results were obtained when roses packaged direct were stored for periods of 5 days or less. This practice resulted in keeping qualities very comparable to those of freshly cut roses.

Packaged roses stored for periods longer than 5 days were occasionally wilted and flaccid when removed from storage. There was a noticeable bluish cast to the flowers and the flowers opened very rapidly.

Discussion:—The results of these tests indicate that roses packaged direct or placed in water for 10 hours or less and then packaged, when stored for periods of 5 days or less are equally as salable and exhibit better keeping qualities than roses stored with their stems in water. These results are attributed to the increased carbon dioxide content and high relative humidity maintained in the enclosed atmosphere of the cellophane package. Table III shows the results of gas analyses of air samples taken from within these packages.

TABLE III—GAS ANALYSIS OF THE ATMOSPHERE WITHIN SEALED PACKAGES OF CUT ROSES

Length of Storage (Days)	Water 24 Hours, Packaged		Packaged Direct	
	CO_2 (Per Cent)	Oxygen (Per Cent)	CO_2 (Per Cent)	Oxygen (Per Cent)
9	9.0	9.1	7.9	10.1
8	4.8	15.6	8.8	10.1
7	6.6	13.4	7.2	12.6
5	5.0	15.6	5.4	14.8
4	4.0	16.6	6.4	13.6
2	2.4	18.4	5.8	14.7

These results are in agreement with those of Thorton (3) who observed beneficial effects on the keeping quality of roses stored at temperatures of 38 degrees to 50 degrees F when the concentration of carbon dioxide ranged between 5 and 15 per cent. He also found detrimental effects when the carbon dioxide storage was extended for a period of 7 days or more. Bancroft (1) also found the rates of respiration and transpiration to be closely correlated with the life of cut flowers. All previous tests depended upon actual injection of CO_2 into the stored package or refrigerator. The tests described show an increase of CO_2 by respiration and not artificial additions of CO_2.

II. Carnations. The tests conducted on carnations were divided into the following treatments:

1. *Packaged Direct:*—Carnations packaged immediately after cutting and then placed in refrigerated storage. The stems are not placed in water until removed from storage.
2. *Water 6 Hours:*—After cutting, carnations placed in water in the refrigerator for 6 hours and then packaged and returned to refrigerator.
3. *Water 24 Hours:*—After cutting, carnations placed in water in the refrigerator for 24 hours and then packaged and returned to refrigerator.
4. *Check:*—After cutting, carnations were bunched and then placed in water in the refrigerator. (This is the normal commercial method of handling cut carnations).

All storage temperatures were maintained at 40 to 45 degrees F. Varieties used throughout the test were: Northland, Casablanca, Virginia Rose, Virginia Miller, Minuet, Millers Yellow, Tom Knipe, and King Cardinal. The above treatments were prepared every other day for 7 days. On the eighth day, all treatments were removed from the refrigerator. The basal end of the stems were cut and flowers placed in water at room temperature (70 to 75 degrees F).

TABLE IV—ACCEPTABILITY OF CUT CARNATIONS AT ROOM TEMPERATURE AFTER 8-DAY STORAGE WITH VARIOUS STORAGE TREATMENTS

Treatment	Time at Room Temperature						
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days
Packaged direct	Good	Good	Good	Good	Good	Fair	Fair
Water 6 hours, packaged	Good	Good	Good	Good	Fair	Fair	Poor
Water 24 hours, packaged	Good	Good	Good	Fair	Fair	Poor	—
Check	Good	Good	Fair	Poor	—	—	—

Carnations packaged direct gave the most satisfactory results of the four treatments, remaining in a good salable condition for 5 to 6 days at room temperature.

Carnations placed in water for 6 hours and 24 hours before packaging were superior to the check treatment but lost their color and showed "sleepiness" from 24 to 48 hours earlier than those packaged direct.

Carnations packaged direct, when stored for periods greater than

TABLE V—Acceptability of Cut Carnations at Room Temperature When Packaged Direct and Stored for Varying Periods of Time

Storage Period (Days)	Time at Room Temperature						
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days
10	Good*	Good	Good	Fair**	Poor†	—	—
8	Good	Good	Good	Good	Good	Fair	Fair
6	Good	Good	Good	Good	Good	Fair	Fair
4	Good	Good	Good	Good	Good	Fair	Fair
2	Good	Good	Good	Good	Good	Fair	Fair

*Good—Carnations maintaining good flower form, color true, and substance good.

**Fair—Carnations maintaining good flower form, slight fading of color or browning at petal margins, substance good.

†Poor—Loss of flower form known to the florist trade as "sleepiness". Definite fading of color or severe browning of petal margins with petals becoming wilted and flaccid.

8 days lose their form and color much more rapidly than those stored 8 days or less.

Check flowers (stems in water) when stored for a period of 8 days lose their color and show "sleepiness" as early as the second or third day at room temperature.

There was no noticeable difference in the keeping qualities of the varieties used in the tests.

Discussion:—The carnation tests have given the most spectacular results obtained through the packaging direct method. Carnations handled in this manner and stored for periods of 8 days or less, lasting 2 to 3 days longer than the check treatments. After 8 days in storage they keep equally as well as freshly cut carnations when placed at room temperature. Carnations, so treated, may be kept in storage for much greater periods and still remain in salable condition when removed from storage. However, the length of time that such flowers remain in an acceptable condition at room temperature is greatly reduced. Neff (2) kept carnations in "dry" storage for 37 days by sealing them in an empty desiccating jar, but they deteriorated rapidly when placed at room temperature.

III. Chrysanthemum (pompon types). Tests on pompon type chrysanthemums were divided into the following treatments:

1. *Packaged Direct:*—After cutting, pompons packaged immediately and placed in refrigerated storage. These stems are not placed in water until removed from storage.
2. *Water 6 Hours:*—After cutting, pompons placed in water in the refrigerator for 6 hours and then packaged and returned to refrigerator.
3. *Water 24 Hours:*—After cutting, pompons placed in water in the refrigerator for 24 hours, and then packaged and returned to refrigerator.
4. *Check:*—After cutting, pompons are bunched and placed in water in the refrigerator. This is the method in present use by commercial growers.

All storage temperatures were maintained at 40 to 45 degrees F. The varieties used in these tests were Souvenir and Omega. The above treatments were prepared daily for 6 days. On the 7th day all treat-

TABLE VI—ACCEPTABILITY OF CUT POMPON CHRYSANTHEMUMS AT ROOM TEMPERATURE AFTER 7-DAY STORAGE WITH VARIOUS STORAGE TEMPERATURES

Treatment	Time at Room Temperature					
	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days
Packaged direct	Good*	Good	Good	Good	Fair†	Fair
Water 6 hours, packaged	Good	Good	Good	Good	Good	Fair
Water 24 hours, packaged	Good	Good	Good	Good	Good	Fair
Check	Good	Good	Good	Good	Good	Fair

*Good—Flowers maintaining good color and form. Substance of flowers and foliage good.
†Fair—Fading of flower color or browning of petal margins together with loss of turgidity or flowers or foliage or both.

ments were removed from storage. The stems were recut and placed in water at room temperature (70 to 75 degrees F).

Packaged pompons, when stored for 7 days or less, gave equally as satisfactory results at room temperature as check treatments, remaining in an acceptable condition for 5 to 6 days.

Pompons which were placed in water for periods of 6 hours or 24 hours before packaging remained in acceptable condition at room temperature approximately 24 hours longer than those packaged direct.

Discussion:—Due to the bulk of cut pompon type chrysanthemums it is necessary to use a large container for packaging. This results in a much larger volume of air within the package, resulting in a greater loss of moisture by plant tissues and longer periods of respiration before an equilibrium is reached within the enclosed atmosphere. The effect of these conditions upon the keeping quality of pompons seems to be lessened by allowing the flowers to stand in water before packaging. Beneficial results were obtained by increasing the humidity within the package by misting the flowers with tap water before enclosing in cellophane. However, with some varieties this causes necrotic areas to be formed on the flower petals.

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Automatic Watering of Roses 1943–1946[1]

By KENNETH POST and JOHN G. SEELEY, *Cornell University, Ithaca, N. Y.*

THE authors (1) previously found no significant difference in production or stem length of roses when the soil was surface watered at 3 inches of capillary tenion, sub-irrigated to saturation at 3 inches of tension or automatically watered by the injection method at 3 or 6 inches of tension.

This paper presents the results of a three-year comparison of surface and automatic injection watering at 3 inches of capillary tension with automatic injection watering at 1 inch of tension. Each treatment was replicated three times with the plots randomized throughout the length of the house.

Dormant budded plants of the variety Peters Briarcliff were planted on April 8, 1943 in shallow V-benches containing 6 inches of a Genesee silt loam which had been composted with one quarter by volume of manure. Each plot was 9 feet long and 3 feet wide with 26 plants per plot planted at a spacing of 12 by 12 inches. The water injection pipe was located in the center of the bench at the end of the plot. Water entered the bottom of the bench through an automatic solenoid valve and moved to the surface by capillarity in the injection watering method.

Water was injected into the automatically watered plots at the rate of ⅓ gallon of water per square foot of bench area at each injection, and none of the water drained from the bench. The surface watered plots received sufficient water to completely saturate the soil when it reached a capillary tension of 3 inches.

Superphosphate (20 per cent) at the rate of 5 pounds per 100 square feet of bench area was thoroughly incorporated in the soil before planting and one application at the same rate was made in the spring of each year. Muriate of potash (½ pound per 100 square feet) was applied in the spring of 1945 and 1946. Nitrogen was supplied in the form of ammonium sulphate (1 pound per 100 square feet) or ammonium nitrate (½ pound per 100 square feet) when the soil test showed less than 25 ppm.

The plots surface watered and automatically watered at 3 inches of tension received 20 applications of nitrogen fertilizer during the experiment while the plots automatically watered at 1 inch of tension received 17 applications. The differences are not statistically significant. All fertilizer applications were made to the soil surface and washed in by means of a heavy surface watering. The automatically watered plots received no other surface watering except that which fell on the soil when the plants were syringed each week.

For the soil tests a representative sample was obtained twice a month by removing from each plot six cores of soil ½ inch in diameter vertically from the top to the bottom of the bench. Each core was divided into halves, one half representing the upper 3 inches of the bench and the other half representing the lower 3 inches. Each six parts were then mixed giving two composite samples for each plot. The samples were air-dried, screened, and analyzed. Nitrates were extracted with the Spurway extracting solution and determined by the phenoldisulfonic method. The results were expressed as parts per million of nitrate in the soil extract.

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[1] This project was started and completed by John G. Seeley. It was supervised by J. E. Howland during 1944 and 1945. Fred F. Horton was the grower and Iva E. Piper the soil technician. The plants were donated by Jackson and Perkins, Newark, N. Y. The project was under the direction of Dr. Kenneth Post.

The plants were maintained in continuous production with gradual cutting back during June and July.

Flowers were cut each morning and graded in 3-inch increments. In this experiment nearly 27,000 flowers were produced on the 234 plants.

RESULTS

Production:—The production and stem length are presented in Tables I and II.

TABLE I—EFFECT OF METHODS OF WATERING ON FLOWER PRODUCTION

Treatment	Average No. Flowers Per Plant			
	1943–44 (11 Months)	1944–45 (12 Months)	1945–46 (10 Months)	Total of Three Seasons
Surface watering at 3 inches ..	34 5	41.8	36.6	112.9
Automatic watering at 3 inches .	34.6	43.1	35.4	113.1
Automatic watering at 1 inch . .	36.9	45.1	34.0	116.0

TABLE II—EFFECT OF METHODS OF WATERING ON STEM LENGTH

Treatment	Average Stem Length (Inches)		
	1943–44	1944–45	1945–46
Surface watering at 3 inches.	22.3	19.9	17.6
Automatic watering at 3 inches.	22.4	20.0	17.9
Automatic watering at 1 inch	22.0	21.1	18.9

No significant difference in rose production occurred when watered on the surface or by automatic injection at the same capillary tension of 3 inches (Table I). Roses automatically watered at 1 inch of tension gave slightly higher production than other treatments but statistical analysis showed the differences were not significant.

The stem length (Table II) was practically the same in all treatments.

Nitrate Levels:—The results of the nitrate tests for the three plots of each treatment watered at 3 inches of tension were averaged and are presented graphically in Fig. 1–3. As noted in previous automatic watering experiments, the trend was for the nitrate content of the upper half of the soil to be higher than the nitrate of the lower half (Fig. 1). The nitrate content of the upper half, however, did not at any time increase to over 100 ppm and during most of the three seasons it ranged between 25 and 65 ppm. This is within the range recommended for roses. The nitrate levels for plots automatically watered at 1 inch of tension were similar to those automatically watered at 3 inches of tension.

Note in Fig. 2 that in the surface watered plots there was little consistent difference in the nitrate content of the upper and lower halves of the benched soil. Usually the lower half of the soil was slightly higher in nitrate than the upper half, but often the reverse was true and the differences were small.

To determine whether the nitrate content of the upper half of the automatically watered plots was significantly different from that in the surface watered plots, a comparison is presented in Fig. 3. It may be seen that the nitrate content of the upper half of the automatically watered soil was sometimes lower and sometimes higher than the ni-

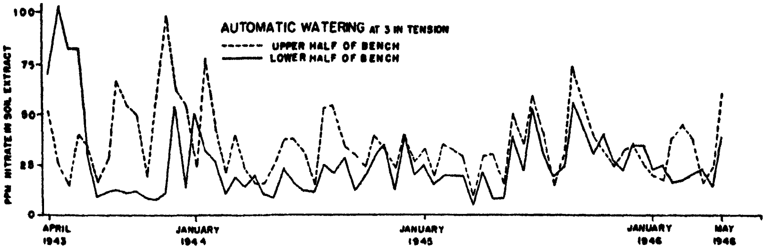

FIG. 1. Nitrate (ppm) in upper and lower half of soil automatically watered by the injection method.

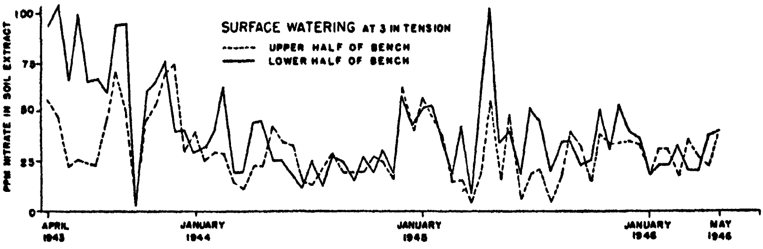

FIG. 2. Nitrate (ppm) in upper and lower half of surface watered soil.

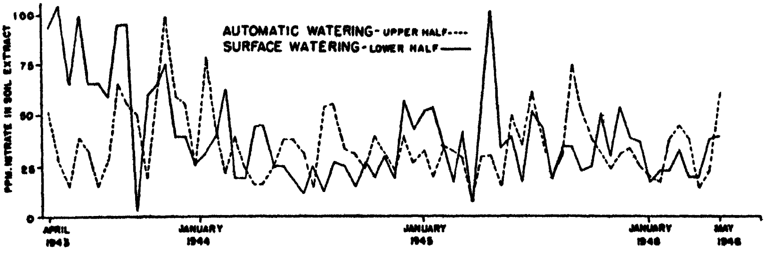

FIG. 3. Nitrate (ppm) in lower half of soil automatically watered and in lower half of surface watered soil.

trate of the surface watered soil, indicating that in general there was little difference in the nitrate levels with the two methods of watering.

SUMMARY

No significant difference in production or stem length of roses resulted whether automatically watered or surface watered at the same capillary tension.

Watering at 1 inch of tension gave no significant increase in production over watering at 3 inches of tension although in the first two years there was a tendency toward higher production when watered at the lower tension.

Since capillary water moves best in soils with low tension, it is recommended that a tension of less than 1 inch be maintained.

The nitrate level in the upper half of automatically watered soil was higher than in the lower half, but on the average not higher than the surface watered soil, and definitely not above the optimum for good growth of roses.

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Experiments in the Handling of Old Rose Plants

By F. F. WEINARD and J. R. KAMP, *University of Illinois, Urbana, Ill.*

MANY growers were obliged in recent years to keep old rose plants which formerly would have been discarded. Since the rearrangement of benches made it necessary to transplant some 4-year-old roses, it seemed an opportune time to try cold storage for the rejuvenation of old plants. It seemed desirable at the same time to determine what would happen if the plants were transplanted without drying-off, contrary to the common practice. Although previous work at the University of Illinois (1) showed injurious effects of prolonged storage on rose plants, recent recommendations of a cold storage treatment (2) made it desirable to consider this as a rejuvenation method.

METHODS

There were four treatments. Half of the plants of a variety were dried off and half were not. Each of these lots was subdivided, half going into cold storage and the remainder being transplanted without the cold treatment. Of the seven varieties planted, Peters' Briarcliff and Token were represented in all treatments.

In the drying-off process over a period of 3 weeks, water was withheld so that the plants began to lose their leaves, but the wood did not shrivel. All plants were cut back to 24 inches on April 25, 1945. Half were packed in boxes with moist sphagnum around the roots and the boxes were placed in storage at 42 degrees F for 4 weeks. The remainder were heeled in until benches were ready, then replanted on May 3. Three weeks later, on May 24, the plants from cold storage were planted. Some of the plants were set in soil and top watered, and the rest in haydite, and subirrigated with a nutrient solution.

Production averages were based on the number of plants at the beginning of the experiment. Where a plant died during the year, it was replaced by a plant of a different variety, so that light conditions would be changed as little as possible, but flowers cut from the new plants were not added to the total for the plot. All nine of the plants which had to be replaced were from the cold storage lot. Eight of these had not been dried off.

RESULTS

The production of flowers by different lots of seven varieties of roses is given in Table I.

In general, drying-off gave the plants no decided advantage or handicap in spite of the fact that the majority of the plants lost had not been dried. The figures for the cold storage treatment were more decisive. The figures show that without exception there were more flowers cut from the plants that were not given the cold storage treatment, compared with the cold storage series. Although these figures represent the total cut from September 1 to June 1, the difference was still evident, although not as marked when the first month's results were removed from consideration. For example, from September 1 to

TABLE I—Flower Production of Roses Grown With and Without Drying Off and Cold Storage

Variety	Number of Plants in Each Treatment	Flowers Cut Per Plant			
		Dried		Not Dried	
		Cold	No Cold	Cold	No Cold
	Soil				
Peters' Briarcliff	16	24.06	24.69	18.81	27.75
Token	16	21.62	28.12	17.81	23.81
Pink Delight	24	22.58	——	20.92	30.83
Sunglow	44	29.57	34.09	28.11	——
	Haydite				
Peters' Briarcliff	16	21.00	29.56	21.94	30.69
Token	16	14.94	26.00	19.50	22.53
Mrs. F. D. Roosevelt	28	28.32	——	28.54	40.78
Peerless	24	21.46	——	23.25	——
Starlite	24	——	30.54	16.79	33.79

June 1, compared with non-cooled plants, cold storaged Peters' Briarcliff gave 24 per cent fewer flowers. For the period October 1 to June 1, the difference was 13 per cent. Similar figures for Token were 25 per cent and 16 per cent, respectively.

Excluding the variety Peerless in which all plants received the cold treatment, a grouping of cut records from all cold and non-cold series for the complete season and the period beginning October 1 are shown graphically in Fig. 1. Evidently the cold storage treatment gave

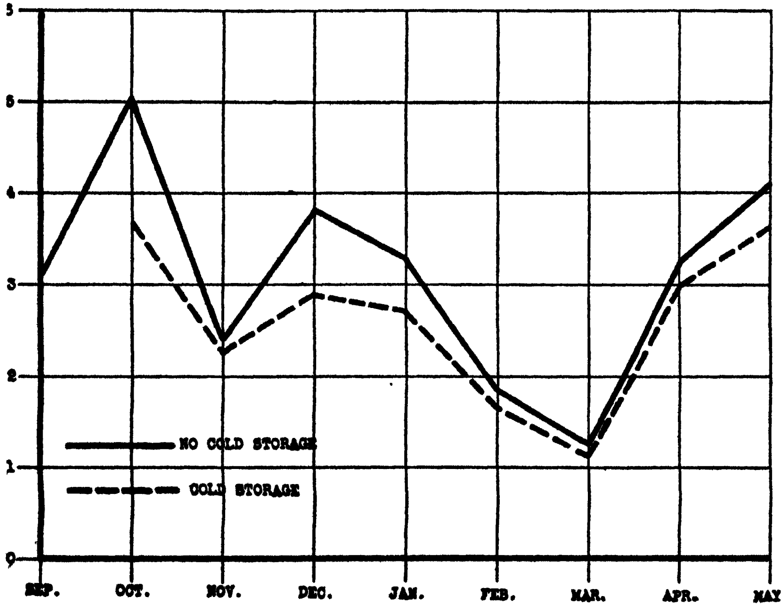

Fig. 1. Average number of flowers per plant per month.

no stimulus sufficient to compensate for the month's production lost at the beginning of the season. In fact, Fig. 1 indicates that production from the cold-storaged plants was slightly lower than from other plants in every month.

Average stem length of flowers (Table II) was not significantly affected by either the drying or cooling of the plants. Any differences in total wood cut (Table III) were due largely to the number of flowers produced.

TABLE II—Stem Lengths of Roses Grown With and Without Drying-Off and Cold Storage

Variety	Number of Plants in Each Treatment	Average Stem Length			
		Dried		Not Dried	
		Cold (Inches)	No Cold (Inches)	Cold (Inches)	No Cold (Inches)
	Soil				
Peters' Briarcliff	16	14.89	15.89	16.53	15 52
Token	16	11.04	10.89	11.02	10.77
Pink Delight	24	19.22	——	18.33	17.59
Sunglow	44	13.68	13.38	13.94	——
	Haydite				
Peters' Briarcliff	16	15.73	16.27	16.11	16.25
Token	16	14.10	11.06	11.21	10.48
Mrs. F. D. Roosevelt	28	14.35	——	14.13	19.93
Peerless	24	17.72	——	15.87	——
Starlite	24	——	15.00	15 09	14 84

TABLE III—Total Wood Cut from Roses Grown With and Without Drying-Off and Cold Storage

Variety	Number of Plants in Each Treatment	Total Wood Cut Per Plant			
		Dried		Not Dried	
		Cold (Inches)	No Cold (Inches)	Cold (Inches)	No Cold (Inches)
	Soil				
Peters' Briarcliff	16	358.19	392.19	311.06	430.69
Token	16	238.69	306.38	196.38	256.56
Pink Delight	24	433.96	——	383.38	542.46
Sunglow	44	404.59	456.09	391.84	——
	Haydite				
Peters' Briarcliff	16	330.25	481.00	353.31	500.75
Token	16	210.56	287.62	218.69	236.20
Mrs. F. D. Roosevelt	28	406.36	——	403.11	812.74
Peerless	24	380.21	——	368.96	——
Starlite	24	——	458.28	298.75	501.67

Examination of the data in Tables I to III disclosed differences in certain treatments in the two growing media. However, when the data were combined for the 332 plants in each medium, the average stem length was not significantly different and the average number of flowers per plant was almost identical. In every case where a comparison was made between plants cooled and not cooled, the trends were the same in haydite as in soil.

Since the preparation of this paper, results of a somewhat similar experiment in drying and cooling of old roses have been published (3). These results are fully in accord with those presented here.

SUMMARY

At least where rose plants are benched in late spring or early summer it is detrimental to subject them to a cold storage treatment. Drying-off of plants may or may not be important, depending upon subsequent handling. Apparently relatively heavy losses of plants will occur if actively growing roses are placed directly into cold storage.

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The Constant Water Level Method of Watering Roses[1]

By KENNETH POST and JOHN G. SEELEY, *Cornell University, Ithaca, N. Y.*

THE early experiments with automatic watering of cut flower crops (1) as well as later experiments (2) show that plants produced as good or better growth when the soil was allowed to dry to only 1 inch of capillary tension as when watered at a greater tension. It is evident that the alternate drying and wetting of soils is not as important in the growth of plants as had been thought by most floriculturists.

The purpose of this experiment was to compare the growth of roses in benches of soil having a constant water level with surface watering at 1, 6 and 10 inches of capillary tension. The experimental plots were 3 feet square and 8 inches deep at the sides, sloping 2 inches from the sides to the middle; they were built of cement and were watertight. Four-inch half tile were placed concave side down, over the middle of the V. Gravel, between ¼ and ½ inch in diameter, was placed in the bench to a depth of 1 inch at the side and leveled across the bench bottom. The bench was then filled with soil to within 1 inch of the top, giving a 6-inch depth of soil. The soil was a Genesee silt loam which had been composted with one-quarter by volume of manure.

Budded plants of the variety Better Times which had been grown in the greenhouse for 3 years were cut back on June 8, 1945. They were heeled in out-of-doors until replanted on June 18. Nine plants were spaced 12 by 12 inches in each plot. Treatments with the constant water level and with surface watering at 1 inch of capillary tension were replicated five times; treatments of surface watering at 6 and 10 inches were replicated four and three times respectively.

The soil of all plots was wet thoroughly by surface watering and from that time the constant water level plots received no further surface waterings except when fertilizer was applied. The surface watered plots were watered when the capillary tension was at 1 inch until July 17, when some of these plots were watered at 6 and 10 inches of capillary tension. Therefore, in the three surface watered treatments the soil was saturated when the tensiometers indicated 1, 6 or 10 inches in the respective treatments. The water table of the constant water level plots was adjusted to the junction of the soil and gravel and maintained there by means of a poultry float valve in a tank on the side of the bench and piped to the center of each plot.

Superphosphate (20 per cent) was incorporated in the composted soil at the rate of 5 pounds per 100 square feet before planting. The soils were tested twice a month and fertilizer applications were made to maintain the nitrate levels between 25 and 100, phosphorus 3 to 8, and potassium 10 to 40 parts per million, Spurway test values (3). Fertilizers were applied to the surface of the soil in all treatments and washed into the soil by means of a heavy surface watering.

For the soil tests a representative sample was obtained twice a month by removing from each plot six cores of soil ½ inch in diameter vertically from the top to the bottom of the bench. Each core was divided into halves, one half representing the upper 3 inches of the bench, and the other half representing the lower 3 inches. Each six parts were then mixed giving two composite samples for each plot. The samples were air-dried, screened, and analyzed. Nitrates were extracted with the Spurway extracting solution and determined by the phenodisulfonic method. The results are expressed as parts per million of nitrate in the soil extract.

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[1] This project was started by J. E. Howland and completed by John G. Seeley. Fred F. Horton was the grower and Iva E. Piper the soil technician. The work was under the direction of Kenneth Post.

Flowers were cut each morning and graded by 3-inch increments. The average production of salable flowers and the stem length are presented in Table I.

TABLE I—Rose Production August 1, 1945–April 30, 1946

	Salable Flowers Per Sq. Ft.	Average Stem Length (Ins)	Average Number Nitrogen Fertilizer Applications July 1, 1945–April 30, 1946
Constant water level.	21.8	20.3	4.0
Surface watering at 1 inch.	22.4	19.7	8.0
Surface watering at 6 inches	19.7	19.7	6.5
Surface watering at 10 inches.	21.0	19.6	6.0

There is little difference in production and stem length with the various treatments, and none of the differences are statistically significant.

In order to determine whether the different water treatments had any effect on production at different times during the year, the monthly production is presented graphically in Fig. 1. There was a slight tendency for the wettest plots (constant water level and surface watering at 1 inch) to produce more flowers in August, September, March and April than the drier plots (surface watering at 6 and 10 inches). The drier plots averaged slightly more production during October, December and January. The differences for any one month are not significantly large and may be due to the cropping tendency of roses.

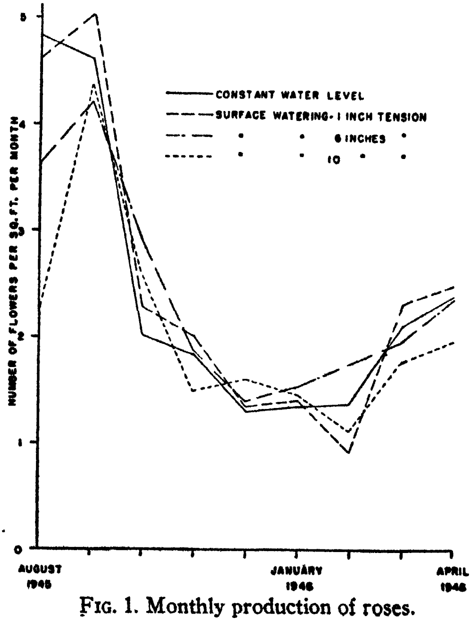

Fig. 1. Monthly production of roses.

FERTILIZER APPLICATIONS

In addition to the initial superphosphate application (5 pounds per 100 square feet), superphosphate was again applied on March 23, 1946. Muriate of potash at the rate of ½ pound per 100 square feet was applied February 5. Applications of nitrogen in the form of ammonium sulphate at 1 pound per 100 square feet or ammonium nitrate at half this rate were applied more frequently. The average number of applications are presented in Table I. The plots with a constant water level required only half as many applications of fertilizer as the surface watered plots. The number of fertilizer applications to the surface watered plots decreased as the tension maintained increased because the drier plots (6 and 10 inches of tension) required fewer waterings than the wettest plots (1 inch) and therefore less fertilizer was leached from the soil.

SUMMARY

No significant difference in production and stem length of roses whether watered by constant water level or surface watered at 1, 6, or 10 inches of tension.

No great difference in the individual monthly production with the four watering treatments.

More nitrogen fertilizer required for surface watered plots than those watered with constant water level.

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MEMBERSHIP ROLL

Abbott, C. E.............University of Florida, Gainesville, Fla.
Abmeyer, Erwin.........Northeast Kansas Exp. Fields, Wathena, Kans.
Acker, Roy M...........5615 S. Campbell, Chicago 29, Ill.
Adamson, Robert M..... Dom. Expt. Sta., Saanichton, B. C.
Adriance, G. W..........A. & M. College of Texas, College Station, Texas
Aggen, A. F.............R. D. 2, Box 260, Camarillo, Calif.
Agnew, Elbert L........58 Charles Ave., Youngstown, Ohio
Alban, E. K.............Ohio Experiment Station, Columbus, Ohio
Alben, A. O.............606 Court House, Shreveport, La.
Alderman, W. H.........University of Minnesota, St. Paul, Minn.
Aldrich, W. W..........Professional Arts Bldg., Hagerstown, Md.
Allen, Albert G....... .Salisbury, Md.
Allen, F. W.............University of California, Davis, Calif.
Allen, Harvey T........Lacombe, Alberta, Canada
Allmendinger, D. F......Wash. Exp. Sta., Vancouver, Wash.
Amerine, Maynard A....University of Calif., Davis, Calif.
Amstein, W. G. .. ..Kansas State College, Manhattan, Kans.
Andersen, E. Milton....Utah State Agr. College, Logan, Utah
Andersen, Emil..........University of Manitoba, Winnepeg, Manitoba
Anderson, F. W.........826 Twenty-second St., Merced, Calif.
Anderson, M. S., Sr. ...Bureau of Plant Industry Station, Beltsville, Md.
Anderson, Robert C.....Univ. of Tenn., Knoxville, Tenn.
Anderson, W. S..........Mississippi State College, State College, Miss.
Andrus, C. F............Veg. Breeding Lab., Box 844, Charleston, S. C.
Anstey, Thomas H........University Farm, St. Paul 1, Minn.
Anthony, R. D...........Penna. State College, State College, Pa.
App, Frank.. ....Seabrook Farms, Bridgeton, New Jersey
Arkell, W. C............10 E. 40th St., New York 16, N. Y.
Armstrong, John A.......408 N. Euclid Ave., Ontario, Calif.
Arnold, Charles Y......Cook County Exp. Sta., Des Plaines, Ill.
Aroian, H. Bruce........Box 818, Blacksburg, Va.
Asen, Sam ....410 Ascot Rd., Oreland, Pa.
Auchter, E. C..... .....Pineapple Research Inst. of Hawaii, Honolulu, T. H.
Austin Lloyd.. .. ....Rainbow Hybridizing Gardens, Placerville, Calif.

Bailey, J. S.... .. ..University of Mass. Amherst, Mass.
Baker, Clarence E......Purdue Univ., Lafayette, Ind.
Baldwin, Herbert E., Jr. Bayberry Orchards, Westport, Conn.
Balog, Pedro P.........University Hotel, Davis, Calif.
Banga, O................Dr. of Inst. for Hort. Plant breeding, 25 Heerenstraat, Wageningen, Holland
Banta, Eldon S..... ....Lebanon, Ohio
Barnes, W. C.......... .Clemson Truck Exp. Sta., Charleston, S. C.
Barnett, R. J ....Kansas State College, Manhattan, Kansas
Barr, C. Guinn..........John Bean Mfg. Co., S. Cedar St., Lansing 4, Mich.
Barss, A. F..............Univ. of British Columbia, Vancouver, B. C.
Batcheller, O. A........Calif. Poly. School, San Dimas, Calif.
Beach, George A........Colo. Agr. College, Ft. Collins, Colo.
Beames, Geoffrey H.....Box 528, Falmouth, Mass.
Beattie, J. H............U. S. Hort. Sta., Beltsville, Md.
Beaumont, J. H..........Hawaii Agr. Exp. Sta., Box 3437, Honolulu 10, Hawaii
Beckenbach, J. R ....The Veg. Crops Lab., Bradenton, Fla.
Beglau, Rolland A......430 N. 15th St., Corvallis, Oregon
Bell, Hugh P.... ....Dalhousie University, Halifax, Nova Scotia
Bell, Robert S..........R. I. State College, Kingston, R. I.
Bennett, J. P............Univ. of Calif., Berkeley 4, Calif.
Beresford, B. C.........Univ. of Minnesota, Crookston, Minn.
Bevan, M. R.............175 Semple Ave., Wpg. Manitoba, Canada
Bhandall, Bir S.........c/o P.S. Muhar Publications Div. Delhi, India
Bhoy, Surendra.........1027 Ocean Ave., Santa Monica, Calif.

Biebel, Joseph P.	312 N. 4th Rd. S. Miami, Fla.
Bieberdorf, G. A.	Okla. A. & M. College, Stillwater, Okla.
Binkley, A. M.	Colo. College, Ft. Collins Colo.
Birkeland, C. J.	818 W. Vine St., Champaign, Ill.
Blackburn, H. W.	Eikenhof Farm, Elgin, C. P., South Africa
Blackmon, G. H.	Univ. of Fla., Gainesville, Fla.
Blaha, Jos. Brno	Zemedelska 3, Czechoslovakia
Blake, M. A.	New Jersey Exp. Sta., New Brunswick, N. J.
Blasberg, Charles H.	University of Vermont, Burlington, Vt.
Bligh, R. D. L.	Experimental Station, Kentville, Nova Scotia
Blodgett, Charles O	529 Hathway Ave., San Louis, Obispo, Calif.
Boller, C. A, Jr.	Oregon State College, Corvallis, Oregon
Boswell, V. R	U. S. Hort. Station, Beltsville, Md.
Bouquet, A. G. B.	Oregon State College, Corvallis, Oregon
Bowers, John L.	Miss. State College, St. College, Miss.
Bowles, Edward J.	2360 Chestnut St., San Francisco 23, Calif.
Boyd, Loyd Q.	6253 Van Buren Ave., Hammond, Ind.
Boynton, Damon	Cornell University, Ithaca, N. Y.
Braathen, E. H.	Bot. 613, Prince George, B. C.
Bradford, F. C.	U. S. Plant Introduction Garden, Glenn Dale, Md.
Bradley, Russell	Purdue University, West Lafayette, Ind.
Brase, Karl D.	N. Y. State Experiment Sta., Geneva, N. Y.
Brasher, E. P.	University of Delaware, Newark, Del.
Bratley, C. O	5202 Roosevelt St., Bethesda 14, Md.
Break, Richard	Room 20, Federal Bldg., Fresno, Calif.
Bregger, J. T	U. S. Soil Conservation Ser. Clemson, S. C.
Brierley, Philip	U. S. Hort. Sta., Beltsville, Md.
Brierley, W. G.	Univ. of Minn., St. Paul, Minn.
Brightwell, W. T.	Georgia Coastal Plain Exp. Sta., Tifton, Ga.
Brittingham, William H	Texas Agr. Exp. Sta., College Station, Texas
Brooks, Reid M.	University Farm, Davis, Calif.
Brown, Bailey, E.	1207 Delafield Pl., N. W., Washington 11, D. C.
Brown, Dillon S.	Research Dept. Hawaiian Pineapple Co. ltd., Honolulu 1, Hawaii
Brown, G. G.	Oregon Agr. Exp. Sta., Hood River, Ore.
Brown, G. B.	Cheyenne Hort. Field Sta., Cheyenne, Wyoming
Brown, H. D.	Ohio State University, Columbus, Ohio
Brown, J. Gailey	University of Calif., Davis, Calif.
Brown, Kenneth E	R. D. 2, Lyons, N. Y.
Brown, Paul D	5046 11th N. E. Seattle, 5, Wash.
Brown, Ralph T.	U.S.D.A. Tung Investigations, Cairo, Ga.
Bryan, O. C.	Florida Southern College, Lakeland, Fla.
Bryant, L. R.	State College of Wash., Pullman, Wash.
Burkholder, C. L	Purdue University, Lafayette, Ind.
Burrell, A. B.	Cornell University, Ithaca, N.Y.
Bushnell, John	Ohio Agrl. Exper. Sta., Wooster, Ohio
Byers, Earl,	Dixie Orchard Co. Rt. 3, Vincennes, Ind.
Cain, John C.	N. Y. State College of Agr., Ithaca, N. Y.
Cain, Robert F.	A. & M. College of Texas, College Station, Texas
Caldis, P. D.	Calif. Packing Co., San Francisco 19, Calif.
Caldwell, J. S.	U. S. Hort. Station, Beltsville, Md.
Cameron, S. H.	University of Calif., Los Angeles, Calif.
Camp, W. B., Jr.	Rt. 1, Box 500, Bakersfield, Calif.
Campbell, John A.	Crystal Springs Exp. Sta., Crystal Springs, Miss.
Campbell, R. W.	Kansas St. College, Manhattan, Kansas
Cardiff, Ira D.	Cardiff & Co. Yakima, Wash.
Carleton, R. Milton	10 W. Randolph St., Chicago 1, Ill.
Carlson, Robert F.	Upper Peninsula Exp. Sta., Chatham, Mich.
Carmon, Y.	Box 47, Tel Aviv, Palestine
Carolus, Robert L.	Mich. State College, East Lansing, Mich.
Carr, Ellwood J.	P. O. Box 195, Walnut Grove, Calif.
Carstens, Martin S.	Western Washington Exp. Sta., Puyallup, Wash.
Carter, Roger, W.	1901½ Orchard Ave., Los Angeles 28, Calif.

Casseres, Ernest H......Inter-American Inst. of Agricultural Sciences,
Turreallia, Costa Rica
Chadwick, L. C..........Ohio State University, Columbus, Ohio
Chandler, W. H.. ......Univ. of Calif., Los Angeles 24, Calif.
Chase, Spencer B.. .. ..Forest Prod. Sec. T. V. A., Norris, Tenn.
Chevalier, Marcel . . .Centre National des Recherches, Agronomiques,
Route de St Ayr, Versailles-Seine et Oise, France
Childers, Norman F. U.S.D.A., A.R.A. Expt. Sta., Mayaguez, Puerto Rico
Childs, W. H... .. .University of W. Va., Morgantown, W. Va.
Christopher, E. P.. . .R. I. State College, Kingston, R. I.
Chroboczek, Emil . .. Osada Palacowa, Skierniewice, Poland
Clapp, Raymond K . .7 Willowbrook Rd., Storrs, Conn.
Clarke, A. E.. . .. .U. S. Hort. Field St., Beltsville, Md.
Clark, B. E.... 805 Birch Road, East Lansing, Mich.
Clark, J. H.. ...... Cranguyma Farm, Long Beach, Wash.
Clarke, James R..... .J. R. Clarke & Son, Milton. N, Y.
Clarke W. S., Jr...... .Box 167, State College, Pa.
Claypool, L. L..... . .University Farm, Davis, Calif.
Clegg, Harold H.. . 1213 Wea Ave., Lafayette, Ind.
Clore, Walter J..... . Irrigation Branch Exp. Sta., College of Wash. Prosser, Wash.
Cochran, George W... The Rockefeller Inst., Princeton, N. J.
Cochran, H. L.... . Pomona Products Co., Griffin, Ga.
Cochran, L. C. ..... .Citrus Exp. Sta., Riverside, Calif.
Cody, L. R....... . Vickery Ave., Saratoga, Calif.
Coit, J. E..... . P. O. Box 698, Fallbrook, Calif.
Collins, C. M. Box 187, Dept. of Agrl. Truro, Nova Scotia
Collins, Wm. H .... Iowa State Hort. Soc., Des Moines, Iowa
Comin, Donald. ... ... Ohio Exp. Station, Wooster, Ohio
Condit, I. J ... .Citrus Exp. Station, Riverside, Calif.
Coombs, Roger C. ...Henniker, N. H.
Cooper, Wm. C. .. . Weslaco, Texas, Box 241
Cotton, Robert H... ...100 Brookline Ave., Boston, Mass.
Coulter, Llemellyn L. .Mich. State College, East Lansing, Mich.
Court,.W. E... ....Box 347, Loomis, Calif.
Cousin, Pierre .... 10 Avenue Dar-El-Maghzen, Rabat, Maroc
Cowart, F. F.. ... Georgia Experiment Sta., Experiment, Ga.
Cram, W. H........ Forest Nursery Station, Indian Head, Sask.
Crane, H. L.......... . Bureau of Plant Industry Sta., Beltsville, Md.
Crane, Julian C.. ... ..Div. of Pomology, U. of Calif. Davis, Calif.
Crawford, Calvin C. . c/o Philippine Packing Corp., Cagayan Misamis
Oriental, Philippine, Is.
Crawford, Carl L...... .1212 Playfield Ave., Prosser, Washington
Croce, Francisco M.....Mendoza, Argentina
Crocker, William. .....Boyce-Thompson Institute, Yonkers, N. Y.
Crummett, Duane O. . N. J. Exp. Station, New Brunswick, N. J.
Cullinan, F. P..... ... Bureau of Plant Industry Sta., Beltsville, Md.
Cumming, Patrick. .... University College, Dundee, Scotland
Currence, T. M...... ..Univ. of Minnesota, St. Paul 1, Minn.
Curtis, Lawrence C ....Conn. Agr. Exp. Sta., New Haven, Conn.
Curtis, O. F., Sr.........Cornell University, Ithaca, N. Y.
Curtis, O. F., Jr... .....N. Y. State Exp. Sta., Geneva, N. Y.

Danielson, L. L ....Va. Truck Exp. Sta., Norfolk 1, Va.
Davenport, S. Lathrop...Worcester, Mass.
Davidson, John H... ...54 Elkenburg St., South Haven, Mich.
Davidson, O. W..... ....New Jersey Experiment Sta., New Brunswick, N. J.
Davis, Glen N ....University of California, Davis, Calif.
Davis, Helen I........ 11 Windsor Ave., Buffalo, N. Y.
Davis, John F..... . ..259 Durand St., East Lansing, Mich.
de Almeida, Carlos R. M Lisboa, Portugal
Dearborn, R. B .... Farmers' Exchange, Springfield, Mass.
de Chaunac, A...........c/o T. G. Bright & Co. Ltd., Niagara Falls, Canada
DeCou, Samuel C........Merchantville, N. J

DE MAISONNEUVE, GERARD	School of Agriculture, Ste. Martine, Quebec
DEONIER, MARSHALL T.	U. S. Hort. Station, Meridan, Miss.
DERMEN, HAIG	Bureau of Plant Industry Sta., Beltsville, Md.
DETJEN, L. R	University of Delaware, Newark, Del.
DETWILER, S. B.	1028 N. Daniel St., Arlington, Va.
DEWEY, DONALD H.	U. S. Hort. Field Sta., R. D. 3, Box 307, Fresno, Calif.
DICKEY, R. D.	Florida Experiment Sta., Gainesville, Fla.
DICKINSON, B. C	Sherwin-Williams Co., Bound Brook, N. J.
DICKINSON, CHARLES E	500 Lafayette St., Jefferson City, Mo.
DICKSON, B. T.	Box 109, Canberra, F. C. T., Australia
DICKSON, W. C., JR	99 George St., Hanover, Pa.
DIXON, JAMES L	Calif. Packing Corp., Box 71, Toppenish, Wash.
DODGE, FREDERICK N	Lee Road, Covington, La.
DOLAN, DESMOND	Rhode Island State College, Kingston, R. I.
DONEEN, L. D	University of California, Davis, Calif.
DORAN, WILLIAM L.	University of Mass., Amherst, Mass.
DORSEY, M. J.	University of Illinois, Urbana, Ill.
DOUD, LORNE J	R. R. 1, Wabash, Ind.
DOWD, OSCAR J.	P. O. Box 71, Paw Paw, Mich.
DRAIN, B. D.	Tennessee Experiment Sta., Knoxville, Tenn.
DREWES, HARM	Oakview Seed Breeding Station, Rochester, Mich.
DUTTON, W. C	523 Bailey St., East Lansing, Mich.
DYE, H. W	Middleport, N. Y.

EASTWOOD, THOMAS M	210 Front St., Delphi, Indiana
ECKERSON, SOPHIA H	Francestown, New Hampshire
EDGECOMBE, S. W	W. Atlee Burpee Seed Co., Doylestown, Pa.
EDGERTON, L. J	Cornell Univ., Ithaca, New York
EDMOND, J. B	Box 266, Mt. Berry, Ga.
EINSET, JOHN	New York Exp. Sta., Geneva, N. Y.
ELLE, GEORGE O.	Texas Tech. College, Lubbock, Texas
ELLENWOOD, C. W	Experiment Station, Wooster, Ohio
ELWELL, ROBERT N	Arrowhead Farm, R. D. 50, Vineyard Haven, Mass.
EMSWELLER, S. L	Bureau of Plant Ind. Sta., Beltsville, Md.
ENGLE, R. H.	616 Investment Bldg., Washington, D. C.
ENZIE, J. V	New Mexico State College, State College, N. M.
ENZIE, W. D	Snider Packing Co., Albion, N. Y.
ERWIN, A. T.	Iowa State College, Ames, Iowa
ESTY, J. RUSSELL.	Natl. Canner's Ass'n., San Francisco 11, Calif.
ETO, WILLIAM H	10301 St. Charles Rd., St. Louis 14, Mo.
EVANS, STERLING.	305 Delaware, Kansas City, Mo.
EWING, MRS. G. C.	1205 Muirlands Dr., LaJolla, Calif.
EYRE, DAVID, R.	1185 Main St., Santa Clara, Calif.
EZELL, B. D	Bureau of Plant Ind. Sta., Beltsville, Md.

FAIRCHILD, S. J	P. O. Box 645, Santa Maria, Calif.
FARBER, RENA.	Agrl. School for Girls, Nahalal, Palestine
FAROOQUI, M. MOHIBULLA	Dept. Agr. 3415 Growliguda, Hyderabad, (Deccan) India
FASLAGIC MEHMEDALIJA	Sarajevo, Bosnia & Herzegovina, Yugoslavia
FAUST, FRANK B.	Assoc. Seed Growers, Inc. Atlanta 2, Ga.
FELBER, IRMA M.	Mich. State College, E. Lansing, Mich.
FERREE, ROY J.	Clemson College, S. C.
FILINGER, GEO. A.	Kansas State College, Manhattan, Kans.
FINCH, A. H	U. S. Dept. Agr. Yuma, Arizona
FISHER, BARRETT	Westville Lab. Barn Hill Rd. Monroe, Conn.
FISHER, D. F	Office of Hort. U.S.D.A., Washington, D. C.
FISHER, D. V.	Dominion Exp. Sta., Summerland, B. C. Canada
FISHER, ELWOOD G	Cornell Univ., Ithaca, N. Y.
FLEMING, H. K	Penn. State College, North East, Pa.
FLOATE, RAY.	Mich. Fruit Canners Inc., Benton Harbor, Mich.
FLORY, WALTER S. JR.	Blandy Exp. Farm, Boyce, Va.
FORD, HARRY W.	Ohio State Univ. Columbus 10, Ohio
FORDE, HAROLD I.	Univ. of Calif., Davis, Calif.

Fossum, M. Truman......Cornell Univ. Ithaca, N. Y.
Foster, A. Alfred.......University of Fla., Exp. Sta., Sanford, Fla.
Francis, James G........N. C. State College, Raleigh, N. C.
Frazier, W. A..........University of Hawaii, Honolulu, Hawaii
French, A. P............University of Mass., Amherst, Mass.
Friend, W. H.......... Texas. Exp. Sta., Weslaco, Texas
Fueglein, J. B. ....Joseph H. Hill Co., Richmond, Ind.
Fullmer, Forrest S......American Potash Inst., Whittier, Calif.
Furr, J. R...............P. O. Box 737, Indio, Calif.

Gabelman, Warren H....P. O. Box 1106, New Haven 4, Conn.
Gardner, F. E.......Bur. Plant Ind., Orlando, Fla.
Garrison, O. B......Clemson Agr. College, Clemson, S. C.
Gauch, H. G............University of Maryland, College Park, Md.
Gerhardt, Fisk..........U. S. Dept. Agr. P. O. Box 99, Wenatchee, Wash.
Gilbert, Franklin A....20 Marvin Lane, New Brunswick, N. J.
Gilgut, C. J..........Waltham Field Sta., Waltham, 54, Mass.
Gill, Denzell, L........Field Lab., Springhill, Ala.
Gould, Wilbur A .... Ohio State Univ., Columbus 10, Ohio
Gramling, A. C., Jr., Mrs.Box 620, Clemson, S. C.
Gray, O. S........... Box 513, Arlington, Texas
Green, Ferris M ..... Colorado Experiment Station, Austin, Colo.
Greenhill, A. W..... Boron Agr. Bureau, Harpenden, Herts, England
Greenleaf, Walter H..Alabama Polytechnic Inst., Auburn, Ala.
Griggs, Wm. H. .... University of Conn. Storrs, Conn.
Grove, Larry C .....Iowa State College, Ames, Iowa.
Guengerich, H. W. . . 901 Tenn. St., Louisiana, Mo.
Gustafson, F. G .... Univ. of Michigan, Ann Arbor, Mich.
Guzman, Victor L.....Head Dept. Agr., Box 2791, Lima, Peru

Haas, A. R. C............Citrus Exp. Sta., Riverside, Calif.
Hagler, T. B........ Alabama Polytechnic Inst., Auburn, Ala.
Hall, Chesley B .....Purdue Univ., Lafayette, Ind.
Haller, M. H......U. S. Hort. Sta., Beltsville, Md.
Halma, F. F........... Univ. of Calif., Los Angeles 24, Calif.
Hamilton, Joseph....... Rt. 1, Box 798, Yuma, Arizona
Hamner, Charles L ....Michigan State College, East Lansing, Mich.
Hankinson, Kenneth....125 King George Rd., Pennington, N. J.
Hanley, J. H............Univ. of Wash. Arboretum, Seattle, Wash.
Hanna, G. C..........Univ. of Calif. Agr. Exp. Sta., Davis, Calif.
Hansen, Carl J.........Univ. of Calif., Davis, Calif.
Hansen, Elmer..........Oregon State College, Corvallis, Oregon
Harbour, F. Bryan.....Tovrea Packing Co., Phoenix, Arizona
Hardenburg, E. V ......Cornell Univ., Ithaca, N. Y.
Hardy, Max B...........U. S. Dept. Agr., Box 60, Albany Ga.
Hargrave, P. D..........Provincial Hort. Sta., Brooks, Alberta, Canada
Harley, C. P...........Plant Ind. Sta., Beltsville, Md.
Harmon, Frank N......R. D. 3, Box 307, Fresno, Calif.
Harmon, Silas A.......Coastal Plain Expt. Sta., Tifton, Ga.
Harrington, J. F....... Univ. of Calif., Davis, Calif.
Harris, R. W...........Univ. of Calif., Davis, Calif.
Hartman, Fred O........523 Hackett Rd., Toledo, O.
Hartmann, Hudson T....Univ. of Calif., Davis, Calif.
Hartman, John D.......Purdue Univ., Lafayette, Ind.
Haut, I. C............ Univ. of Maryland, College Park, Md.
Havis, John R...........Cornell Univ., Ithaca, N. Y.
Havis, Leon.............Bureau of Plant Ind., Beltsville, Md.
Hawthorne, Leslie R....U.S.D.A. Utah Exp. Sta., Logan, Utah
Hawthorne, P. L........Tupelo Chamber of Commerce, Tupelo, Miss.
Hayes, W. B..............Agrl. Inst., Allahabad, India
Hayward, H. E..........U. S. Regional Salinity Lab., Riverside, Calif.
Hazlewood, Harry......c/o Hazlewood Bros. Pty. Ltd., Box 1, Epping, New South Wales

HECHLER, CHARLES, JR.	Box 304, Roslyn, New York
HEINICKE, A. J	N. Y. State Exp. Sta., Geneva, N. Y.
HENDRICKSON, A. H	Univ. of Calif., Davis, Calif.
HENDRIX, J. WALTER	Hawaii Agr. Exp. Sta., Univ. of Hawaii, Honolulu
HERMAN, J. R	San Francisco Junior College, Berkeley, Calif.
HESTER, JACKSON B	Campbell Soup Co., Riverton, N. J.
HEWITT, W. B	Univ. of Calif. Exp. Sta., Davis, Calif.
HIBBARD, A. D	Univ. of Missouri, Columbia, Mo.
HIKIDA, ROBERT H	Univ. of Manitoba, Winnipeg, Manitoba
HILDEBRAND, E. M	Texas A. & M. College, College Station, Texas
HILDRETH, A. C	Cheyenne Hort. Sta., Cheyenne, Wyo.
HILL, ROBERT G., JR	Univ. of Maryland, College Park, Md.
HILTON, R. J.	Univ. of Alberta, Edmonton, Alberta
HIROSHIGE, HERBERT M	1294 College Walk, Honolulu 22, T. H.
HITCHCOCK, A. E	Boyce-Thompson Inst , Yonkers, N. Y.
HITZ, C. W	Maine Agrl. Exp. Sta., Orono, Maine
HOADLEY, ALFRED D	Campbell Research Farm, Riverton, N. J
HOAGLAND, D. R	Univ. of Calif., Berkeley, 4, Calif.
HOFFMAN, I. C.	Ohio Exp. Sta., Wooster, O.
HOFFMAN, J. C	Everglades Exp. Sta., Belle Glade, Fla
HOFFMAN, M. B	Cornell Univ., Ithaca, N. Y.
HOFFMAN, ROBERT M	Univ of Calif. Red Bluff, Calif.
HOLLAR, VICTOR E	Fordhook Farms, Doylestown, Pa
HOLLEY, W. D	A. N. Pierson, Inc , Cromwell, Conn.
HOLMES, ARTHUR	Madisonville Rd., Basking Ridge, N. J
HOPE, CLAUDE	Apartado 18, Turrialba, Costa Rica
HOPP, RICHARD	Vermont Agr. Exp. Sta., Burlington, Vt
HORN, ANTON S	Univ. of Idaho, Boise, Idaho
HORSFALL, FRANK, JR	Virginia Agrl. Exp. Sta., Blacksburg, Va.
HOUGH, W. S	Winchester Research Lab., Winchester, Va
HOWARD, FRANK L.	R. I. Agrl. Exp. Sta., Kingston, R. I.
HOWARD, W. L	Univ of Calif., Davis, Calif.
HOWLAND, JOSEPH E	Better Homes & Gardens, Des Moines 3, Iowa
HOWLETT, F. S	Ohio Exp. Sta., Wooster, Ohio
HOYLE, BURTON J	Tulelake Exp. Sta., Tulelake, Calif.
HUBBARD, LEON V	General Foods Corp , Hillsboro, Ore
HUDSON, N. D	Room 20, Federal Bldg., Fresno, Calif
HUELSEN, W A.	Univ of Ill , Urbana, Ill.
HUGHES, MORRIS B	Edisto Experiment Sta. Blackville, S. C
HUME, EDWARD P	Federal Exp. Sta., Mayaguez, Puerto Rico
HUNKLE, V. H	797 N. Milwaukee St., Milwaukee 1, Wis
HUTCHINS, A. E	Univ. of Minn., St. Paul, Minn.
HUTCHINS, LEE M	Bureau of Plant Ind. Sta., Beltsville, Md

IMPERIAL AGRL. BUREAU	32 Victoria St. S. W. 1, England
ISAAC, E. E	Montana State College, Bozeman, Mont.
ISBIT, ARTHUR	Cornell Univ., Ithaca, N. Y.
ISVAN, AHMET	Univ. of Calif., Davis, Calif.
IVANOFF, S. S	Miss., Agr. Exp. Sta., State College, Miss
IVERSON, VINCENT E	Univ. of Montana, Bozeman, Mont.

JACOB, H. E	Univ. of Calif., Davis, Calif.
JACOBS, HOMER L	Davey Tree Expert Co., Kent, Ohio
JAMISON, F. S	Univ. of Fla., Gainesville, Fla.
JANES, BYRON E	Univ. of Fla., Gainesville, Fla.
JOHN, CHARLES A	Assoc. Seed Growers, Franklin, Ind.
JONES, WINSTON W	Citrus Exp. Sta., Riverside, Calif.
JOHNSON, CONRAD C	Insecticide Div. Innis, Speiden & Co., N. Y. 6, N.Y.
JOHNSTON, E. C	Chas. H. Lilly Co., Albany, Oregon
JOHNSTON, H. G	University of Texas, Austin, Texas
JOHNSTON, J. C	Citrus Exp. Sta., Riverside, Calif.
JOHNSTON, STANLEY	Mich. Exp. Sta., South Haven, Mich.
JOLEY, LLOYD E	Box 1040, Chico, Calif.
JONES, FRANKLIN D	American Chem. Paint Co., Ambler, Pa.

Jones, H. A.	U. S. Hort. Sta., Beltsville, Md.
Jones, Linus H.	University of Mass., Amherst, Mass.
Jones, Robert E.	Church Grape Juice Co., Kennewick, Wash.
Jones, Robert W.	Citrus Exp. Sta., Lake Alfred, Fla.
Jones, S. E.	Texas Agr. Exp. Sta., College Station, Texas
Judkins, Wesley P.	Ohio Exp. Sta., Wooster, Ohio
Jungerman, A. A.	Stanislaus Co., Farm Advisor, Box 1028, Modesto, Calif.
Kalin, Elwood W	Wash. State College, Pullman, Wash.
Kalmar, A. F	Food Machinery Corp., Riverside, Calif.
Kamp, James R.	Univ. of Ill., Urbana, Ill.
Kapuler, B.	Mikveh-Israel Agrl. Sta., P. O. Box 185, Tel-Aviv, Palestine
Karr, Chadwick	Rt. 7, Yakima Wash.
Kasimatis, Amandus, N.	West Hall, Davis, Calif.
Kaas, Miryan Z.	Kibbutz Gimel, Rishon LeZion, Palestine
Katyal, Sham Lal	Mich. State College, East Lansing, Mich.
Keenen, F. G.	E. I. DuPont De Nemours & Co., Wilmington 98, Del.
Keener, R. L.	The University of Georgia, Athens, Ga.
Kelly, C. B.	Hortl. Exp. Sta., Vineland Station, Ontario
Kelly, William C.	U. S. Plant, Soil & Nutrition Lab., Ithaca, N. Y.
Kelsall, A.	Experiment Sta., Kentville, N. S.
Kanworthy, Alvin L.	Univ. of Delaware, Newark, Del.
Kessler, George M.	Penn. State College, State College, Pa.
Khan, Fazlur Rahim.	Univ. Farm Campus, St. Paul 1, Minn.
Kienholz, J. R.	U. S. Fruit Disease Laboratory, Hood River, Ore.
Kikuta, K.	University of Hawaii, Honolulu, T. H.
Kimbrough, W. D.	Louisiana State University, University, La.
Kiplinger, D. C.	Ohio State University, Columbus, Ohio
Kitchen, E. M.	51 Madison Ave., New York City
Knott, J. E.	University of California, Davis, Calif.
Knowles, John T.	Libby, McNeill & Libby, Blue Island, Ill.
Kohner, Bertha E.	3212 Northampton St., N. W., Washington 15, D. C.
Koudal, Elizabeth	Box 55, LaConner, Wash.
Kramer, Amihud.	30 S. Crescent Road, Greenbelt, Md.
Krantz, F. A.	University of Minnesota, St. Paul, Minn.
Kraus, E. J.	University of Chicago, Chicago 37, Ill.
Kraus, James E.	Univ. of Idaho Agrl. College, Moscow, Idaho
Krezdorn, A. H.	College of Texas, College Station, Texas
Krochmal, Arnold	New Mexico College, State College, N. M.
Lachman, Wm. H.	Univ. of Mass., Amherst, Mass.
Lana, Edward P.	Iowa State College, Ames, Iowa
Landon, R. H.	University of Minnesota, St. Paul, Minn.
Larson, Russell	Pennsylvania State College, State College, Pa.
Lassiter, Judson H.	Box 2817, University Station, Gainesville, Fla.
Latimer, L. P.	University of New Hampshire, Durham, N. H.
Lavoie, J. H	Department of Agriculture, Quebec, Canada
Leach, Hon. Will	Judges Chambers, Scranton, Pa.
LeClerg, E. L	1724 F. St., N. W. Washington 25, D. C.
LeCrone, Fred	Dept. of Hort., Okla. A & M Col., Stillwater, Okla.
Lee, Shu Hsien	403 Ann Street, East Lansing, Mich.
Leonard, Oliver A.	Miss. Expt. Sta., State College, Miss.
Lenz, Fred.	R. D. 1, Box 279, Homestead, Fla.
Lepage, Rene	Ingenieur-Agr. E. S. A., 45 Rue Chevre, Angers, M. & L. France
Lesley, J. W.	Citrus Experiment Station, Riverside, Calif.
Leslie, E. H.	Traver Road, Ann Arbor, Mich.
Lessard, Pierre	Frelightsburg, Missisquoi-City, Quebec, Canada
Levering, S. R.	Ararat, Va.
Lewis, F. H.	Fruit Research Laboratory, Arendtsville, Pa.
Lilleland, Omund	University of California, Davis, Calif.
Lindner, R. C.	1009 Vassar St., Wenatchee, Wash.

Link, Conrad B	Brooklyn Botanic Garden, Brooklyn, N. Y.
Lloyd, J. W	524 N. San Gabriel Blvd., San Gabriel, Calif.
Lobenstein, Chas. W	Kansas State College, Manhattan, Kansas
Loehwing, W. F	University of Iowa, Iowa City, Ia.
Long, D. D	20 N. Wacker Drive, Chicago, Ill.
Long, E. M	Continental Mexican Rubber Co., Torreon, Coah, Mex.
Longley, L. E	Univ. Farm, St. Paul, Minn.
Loomis, N. H	U. S. Horticultural Station, Meridian, Miss.
Loomis, W. E	Iowa State College, Ames, Ia.
Lorenz, O. A	University of California, Davis, Calif.
Lowman, M. S	Bureau of Plant Ind. Sta., Beltsville, Maryland
Lucas, I. B	Markdale, Ontario
Luce, W. A	2311 Barge Ave., Yakima, Wash.
Lumsden, D. V	8700 Colesville, Rd., Silver Spring, Md.
Lyon, A. V	Commonwealth Research Sta., Merbein, Australia
Lyon, C. B	Hawaiian Pineapple Co., Honolulu, T. H.

MacDaniels, L. H	Cornell University, Ithaca, N. Y.
MacGillivray, J. H	University of California, Davis, Calif.
McClintock, J. A	Purdue Univ., Lafayette, Ind.
McCollam, Millard E	American Potash Inst. Inc., San José, Calif.
McCubbin, E. N	Univ. of Florida, Hastings, Fla.
McCue, C. P., Jr	Appledore Orchard, Greenwood, Va.
McDaniel, J. C.	403 State Office Bldg., Nashville, Tenn.
McElroy, Leona A	Fortin Road, Kingston, R. I.
McGinty, R. A	S. C. Experiment Sta., Clemson, S. C.
McHatton, T. H.	State College of Agriculture, Athens, Ga.
McKay, John W	Bureau of Plant Ind. Sta., Beltsville, Md.
McLellan, R. I	E. W. McLellan Co., Colma, Calif.
McMahon, M. L	Box 112, Lanai City, Hawaii
McNamee, R. W	Carbide & Carbon Chem. Corp., N. Y. City, N. Y.
Mack, W. B	Pennsylvania State College, State College, Pa.
Magistad, O. C	U. S. Regional Salinity Lab., Riverside, Calif.
Magness, J. R	Bureau of Plant Industry Sta., Beltsville, Md.
Magruder, Roy	Bureau of Plant Industry Sta., Beltsville, Md.
Mahoney, C. H	c/o Natl. Canners Assoc., Washington, D. C.
Majewski, F	Col. of Agr., Rakowieckah 8, Warsaw, Poland
Mallison, E. D	The Atlantic Commission Co. N. Y. City, N. Y.
Mann, Louis K	Univ. of Calif., Davis, Calif.
Marks, Richard T	California Packing Corp., Merced, Calif.
Marsh, R. S	University of West Virginia, Morgantown, W. Va.
Marshall, R. E	Michigan State College, East Lansing, Mich.
Martin, William E	University of California, Berkeley, Calif.
Mather, T. H	506 Marine Bldg., Vancouver, B. C.
Mathisen, S. S	9722 Watertown Plank Rd., Milwaukee 13, Wisconsin
Matkin, O. A	Agrl. Laboratory, P. O. Box 308, Orange, Calif.
Matsuura, Minoru	P.O. Box 1882, Hilo, Hawaii
Mattson, Harold	N. D. State College, Fargo, N. D.
Mattus, G. E	Pomology Dept. Cornell U., Ithaca, N. Y.
Meader, E. M	Pittsfield, N. H.
Mecartney, J. L	Pennsylvania State College, State College, Pa.
Mecca, Sebastian	2346 Sedgley Ave., Philadelphia, 32, Pa.
Meiss, Alfred N	114 Whitney Ave., New Haven 10, Conn.
Mendall Seaton C	Hammondsport, N. Y.
Mero, Robert S	Hampton Inst., Hampton, Va.
Merrill, Grant	Box 877, Red Bluff, Calif.
Merrill, Samuel, Jr	U. S. Tung Laboratory, Bogalusa, La.
Merrill, T. A	Washington State College, Pullman, Wash.
Metcalf, Homer	University of Montana, Bozeman, Mont.
Michael, Ralph	Texas Agrl. Exp. Sta., Gilmer, Texas
Michalski, L. A	Highways Branch, Legislative Bldg., Winnipeg, Can.
Miller, Cloy M	Yoder Bros., Barberton, Ohio
Miller, J. C	Louisiana State University, University, La.

Milne, C. G	Purdue University, Lafayette, Ind.
Minges, P. A	University of California, Davis, Calif.
Mitchell, Arthur, E	Michigan State College, East Lansing, Mich.
Moll, Alvin C	Ohio State University, Columbus, Ohio
Moon, Hubert H	Bureau of Plant Industry Sta., Beltsville, Md.
Moore, E. C	517 S. Church St., Visalia, Calif.
Moore, J. G	University of Wisconsin, Madison, Wis.
Moore, Paul W	Rt. 1, Box 30, Azusa, Calif.
Moore, Rufus H	University of Nebraska, Lincoln, Nebr.
Moore, W. D	501 S. Andrews Ave., Ft. Lauderdale, Fla.
Morris, H. F	Texas Experiment Station, Nacogdoches, Tex.
Morris, Leonard L	Univ. of Calif., Davis, Calif.
Mortensen, E.	Texas Experiment Station, Winter Haven, Tex.
Mowry, Harold	University of Florida, Gainesville, Fla.
Mulligan, Brian, O	Univ. of Wash. Arboretum, Seattle 5, Wash.
Mullison, W. R	2010 Ashman St., Midland, Mich.
Munger, Henry M	Cornell University, Ithaca, N. Y.
Murneek, A. E	University of Missouri, Columbia, Mo.
Murphy, Paul	8 Stanley Rd., Oxford, England
Musser, James L	Charter Seed Co., Twin Falls, Idaho
Myhre, Arthur	Western Washington Exp. Sta., Puyallup, Wash.

Neary, M. E	Dept. Agriculture & Marketing, Kentville, Nova Scotia
Neff, Marshall S	U. S. Field Lab. for Tung, Investigations, Cairo, Ga.
Nettles, V. F	University of Florida, Gainesville, Fla.
Newcomb, D. Albert	Foothill Laboratories, Corona, Calif.
Nightingale, G. T	Pineapple Research Institute, Honolulu, T. H.
Nixon, Roy W	U. S. Date Garden, Indio, Calif.
Nordine, Roy, M	The Morton Arboretun, Lisle, Ill.
Nordlinger, E. W	139 N. Clark St., Chicago, Ill.
Northup, R. C	Forest Ave., Newport, R. I.
Nylund, R. E	Univ. Farm, St. Paul 1, Minn.

Ogle, Robert E	Univ. of Tenn., Exp. Sta., Knoxville, Tenn.
Olmo, H. P	University of California, Davis, Calif.
Opitz, Karl	Germain Seed & Plant Co., Camarillo, Calif.
Oppenheimer, H. R	Agrl. Research Sta., Rehovot, Palestine
O'Reilly, H. J	The Dallas Experimental Area, The Dallas, Oregon
O'Rourke, Francis L	Mich. State College, East Lansing, Mich.
Osuna, Pedro	Rio Piedras, Puerto Rico
Overcash, J. P	Mississippi State College, State College, Miss.
Overholser, E. L	Hort. Dept. Va. Poly. Institute, Blacksburg, Va.
Overley, F. L	Fruit Brand Exp. Sta., Wenatchee, Wash.

Paddock, Elton F	Ohio State University, Columbus, Ohio
Page, E. M	101 Chouteau Ave., St. Louis, Mo.
Palmer, E. F	Vineland Station, Ontario, Canada
Palmer, R. C	Experiment Station, Summerland, B. C.
Palmiter, D. H	Experiment Sta., Cottage Rd., Poughkeepsie, N. Y.
Pancoast, Harry M	Food Machinery Corp., San José, Calif.
Papaioannou, P	Univ. of Calif., Davis, Calif.
Parker, E. R	Citrus Experiment Station, Riverside, Calif.
Parmenter, Read	Suncook, N. H.
Partridge, N. L	Michigan State College, East Lansing, Mich.
Patel, G. I	University of Calif., Davis, Calif.
Paur, Sherman	606 S. Allen St., State College, Pa.
Peacock, N. D	University of Tennessee, Knoxville, Tenn.
Pearson, Harold E	Box 38, LaVerne, Calif.
Pearson, O. H	Box 1482, West Springfield, Mass.
Peirce, L. B	Elgin Co-op. Fruitgrowers Ltd., P. O. Box 21, Elgin, C. P.
Pelkey, Robert D	Univ. of Nebraska, Lincoln 1, Neb.
Pelton, W. C	Univ. of Tenn., Knoxville, Tenn.

Pentzer, W. T.	Un S. Dept. Agr. Fresno, Calif.
Peters, Robert B.	739 N. 7th St., Allentown, Pa.
Peterson, C. E.	Iowa Agr. Exp. Sta., 312 Hort. Bldg., Ames, Iowa
Peterson, Lewis E.	Muscatine Island Field St., Fruitland, Iowa
Pickett, Barzillai S.	Hort. Dept. U. of Georgia, Athens, Ga.
Pieniazek, S. A.	Institute of Pomology, Osada Palacowa, Skierniewice, Poland
Platenius, Hans	Estacion Central de Colonizacion, en Tingo Maria, via Lima, Peru
Poesch, G. H.	1741 Cardiff Road, Columbus, Ohio
Popenoe, Wilson	Escuela Agricola Panamericana, Tegucigalpa, Honduras, C. A.
Porter, Alton M.	22 Manor Circle, Takoma Park, Md.
Porter, D. R.	P. O. Box 1406, Campbell Soup Co., Sacramento, Calif.
Powers, LeRoy	Hort. Field Sta., Box 1250, Cheyenne, Wyo.
Pratt, A. N.	American Fruit Growers, Box 1202, Roanoke, Va.
Pratt, Harlan K.	Div. Truck Crops, U. of Calif., Davis, Calif.
Proebsting, E. L.	University of California, Davis, Calif.
Prushek, E.	Rt. 3, Niles, Mich.
Pryor, Dean E.	3630 E. Colorado St., Pasadena, Calif.
Pyle, Robert	Conrad-Pyle Co., West Grove, Pa.

Qazilbash, N. A.	Islamia College, Peshawar, N.W.F.P., India

Ragland, C. H.	Mississippi State College, State College, Miss.
Rahn, E. M.	University of Delaware, Newark, Dela.
Raisinghani, Bhawan Ratumal	Michigan State College, East Lansing, Mich.
Raleigh, G. J.	Cornell University, Ithaca, N. Y.
Randall, Thomas E	Wash. State College, Pullman, Wash.
Randolph, U. A.	Texas Agr. Exp. Sta. Montague, Texas
Randhawa, G. S.	Ontario Agr. College, Guelph, Ontario
Rao, S. Madhava	Dept. Agr., Ootacamund, S. India
Rasmussen, E. J.	University of New Hampshire, Durham, N. H.
Rawlings, C. O.	Hort. Dept. Oregon State College, Corvallis, Oregon
Reed, C. A.	Bureau of Plant Industry Sta., Beltsville, Md.
Reed, H. J.	Purdue University, Lafayette, Ind.
Reed, H. M.	Texas Experiment Station, Angleton, Tex.
Reeves, E. L.	U. S. Dept. Agrl., Box 99, Wenatchee, Wash.
Reger, M. W.	Calif. Packing Corp., Toppenish, Wash.
Rehder, Alfred	Arnold Arboretum, Jamaica Plain, Mass.
Reimer, C. A.	South Haven, Mich.
Reiter, Victor	1195 Stanyan St., San Francisco, Calif.
Relyea, Kenneth E.	Farmers Seed and Nursery Co., Fairbault, Minn.
Reuther, Walter	415 N. Parramore St., Orlando, Fla.
Ribbe, John	North Star Ranch, Malott, Wash.
Richardson, H. B.	3864 Ramona St., Riverside, Calif
Rick, C. M., Jr.	University of California, Davis, Calif.
Riley, Harland K.	Box 44, S. L. I, Lafayette, Louisiana
Riner, Mary Edith	Biology Dept., Stanford, Univ. Palo Alto, Calif.
Riollano, Arturo	Agrl. Exp. Substa. Isabela, P. R.
Rivero, M. J.	Dept. Nacional, 552 Bogota, Columbia, S. A.
Roberts, A. N.	Oregon State College, Corvallis, Ore.
Roberts, Edith A.	Vassar College, Poughkeepsie, N. Y.
Roberts, John W.	1600 Lake Ship Drive, Winter Haven, Fla.
Robertson, W. H.	Department of Agriculture, Victoria, B. C.
Roessler, E. B.	University of California, Davis, Calif.
Roever, W. E.	97 Lafayette St., Stamford, Conn.
Rollins, C. F.	P. O. Box 981, Clearwater, Fla.
Romberg, L. D.	U. S. Pecan Field Sta., Brownwood, Texas
Romshe, F. A.	Okla. A. & M. College, Stillwater, Okla.
Roqueta, Ramon Sala	Spanish Consulate, Patronato de Biologia Aplicada de Bon Repos, Diputacion, Lerida, Spain

Rose, J. W.	Michigan State College, E. Lansing, Mich.
Russell, C. E.	Mich. State College, East Lansing, Mich.
Ryall, A. Lloyd	Harlingen, Tex.
Ryerson, K. A.	University of California, Davis, Calif.
Rygg, G. Leonard	U. S. Hort. Field Lab., Pomona, Calif.
Samisch, Rudolf	Agrl. Expt. Sta., Rehovot, Palestine
Savage, Earl F.	Georgia Expt. Sta., Experiment, Ga.
Sax, Karl	Bussey Institute, Forest Hills, Mass.
Schaefer, A. J.	Route 32, Newburgh, N. Y.
Schmidt, Robert	N. C. State College, Raleigh, N. C.
Schneider, G. W.	Hort. Dept. Rutgers Univ., New Brunswick, N. J.
Schoonover, W. R.	University of California, Berkeley, Calif.
Schrader, Otto Lyra	Rua Santa Clara, 256 Copacabana, Rio de Janeiro, Brazil
Schroeder, C. A.	University of California, Los Angeles, Calif.
Schroeder, Raymond A.	U. of Missouri, 205 Whitten Hall, Columbia, Mo.
Schubert, Oscar E.	University of Illinois, Urbana, Ill.
Scott, D. H.	Bureau of Plant Industry Station, Beltsville, Md.
Scott, L. B.	Regional Nurseryman, Montgomery Bldg., Spartanburg, S. C.
Scott, W. C.	U. S. Fruit & Veg. Products Lab., Weslaco, Tex.
Scudder, Walter T.	Dept. of Veg. Crops, Cornell U., Ithaca, N. Y.
Seeley, J. G.	N. Y. State College of Agrl., Ithaca, N. Y.
Sefick, Harold I.	Clemson Agricultural College, Clemson, S. C.
Sekhon, B. S.	Ohio State Univ., Columbus, Ohio
Senn, T. L.	The Clemson Agr. College, Clemson, S. C.
Serpa, Diego	Univ. of Calif., Davis, Calif.
Sharpe, Ralph H.	U. S. Pecan Exp. Sta. R. D. 1, Shreveport, La.
Shaulis, Nelson J.	New York Experiment Station, Geneva, N. Y.
Shaw, E. J.	412 West Sixth St., Los Angeles, Calif.
Shelton, R. F.	Texas Agr. Exp. Sta., Tyler, Texas
Shepard, Paul H.	Missouri State Fruit Expt. Sta., Mountain Grove, Mo.
Shifriss, Oved	Fordhook Farms, Doylestown, Pa.
Shoemaker, J. S.	Ontario Agr. College, Guelph, Canada
Showalter, Robert K.	Florida Experiment Station, Gainesville, Fla.
Shutak, V. G.	Rhode Island State College, Kingston, R. I.
Sidwell, A. P.	Maunaloa, Molokai, T. H.
Siegelman, Harold W.	Univ. of Calif., Los Angeles 24, Calif.
Simpson, Robert C.	Rt. 1, Vincennes, Ind.
Sinclair, W. B.	Citrus Experiment Station, Riverside, Calif.
Sitton, B. G.	U. S. Tung Laboratory, Bogalusa, La.
Skinner, H. T.	Morris Arboretum, Chestnut Hill, Pa.
Skok, John	University of Illinois, Urbana, Ill.
Slate, G. L.	New York Experiment Station, Geneva, N. Y.
Smith, Edwin	U. S. Dept. Agr., Wenatchee, Wash.
Smith, George E.	Riverton, N. J.
Smith, John A.	Box 204, Oliver, B. C., Canada
Smith, John D.	R. R. 5, Tipton, Indiana
Smith, Ora	Cornell University, Ithaca, N. Y.
Smith, Paul F.	U. S. Subtropical Fruit Field Sta., Orlando, Fla.
Smith, Paul G.	University of California, Davis, Calif.
Smock, R. M.	Cornell University, Ithaca, N. Y.
Snyder, Elmer	U. S. Experiment Vineyard, Fresno, Calif.
Snyder, W. E.	Agr. Exp. Sta. Cornell U., Ithaca, N. Y.
Southwick, F. W.	Cornell University, Ithaca, N. Y.
Southwick, Lawrence	1422 W. Carpenter St., Midland, Mich.
Southwick, Roy W.	563 Murray St., Porterville, Calif.
Souty, J.	Sta. D'Arboriculture Fruitiere, Domaine de la Grande-Ferrade, Pont De La Maye Gironde, France
Sparks, Walter	Colorado State College, Ft. Collins, Colo.
Stair, E. C.	Purdue University, Lafayette, Ind.

Stajano, Alberto Basso	Av Gral Flores 2220, Montevideo, Uruguay
Stanfield, J. Fisher	Miami University, Oxford, Ohio
Stankovic, Dusan	Univ. of Belgrade, Zemun, Yugoslavia
Starcher, Doyle B	P. O. Box 811, Chelan, Wash.
Stark, Paul, Jr	Louisiana, Mo. Stark Bro. Nurseries
Steelman, C. H., Jr	Rt. 2, Box 2–316, Princeton, N. J.
Steinbauer, C. E	Bureau of Plant Ind. Sta., Beltsville, Maryland
Steuk, William K	Rt. 2, Sandusky, Ohio
Stevens, W. R	Bastia Hill, Wanganui, N. Z.
Stier, H. L	101 Barron St., Takoma Park, Md.
Stout, A. B	New York Botanical Garden, New York City
Stoutemyer, V. T	University of California, Los Angeles 24, Calif.
Struckmeyer, B. Esther	University of Wisconsin, Madison, Wis.
Stuart, N. W	Bureau of Plant Industry Sta., Beltsville, Md.
Stuckey, H. P	Georgia Expt. Sta., Experiment, Ga.
Sudds, R. H	West Virginia University, Morgantown, W. Va.
Supt	Dominion Expl. Sta. Harrow, Ontario, Canada
Swanson, Clark H.	Rt. 2, Escalon, Calif. Box 907
Swartley, John C	406 Bethlehem Pk., Philadelphia 18, Pa.
Sweet, R. D	Cornell University, Ithaca, N. Y.
Swim, H. C	Armstrong Nurseries, Ontario, Calif.
Swingle, C. F	630 Fremont St., Manhattan, Kansas
Syamal, Nirode Baron	College of Agr. Univ. of Calif. Davis, Calif.
Tai, Egbert A	Dept. of Agrl. Kingston, Jamaica
Talbert, T. J	Univ. of Missouri, Columbia, Mo.
Tate, H. D	Agrl. Research Lab., R. D. 1, Bethany, Conn.
Tawse, W. J.	5659 Terrebonne Ave., Montreal, Canada
Teague, C. P	309 Rimpau Ave., Corona, Calif.
Teske, A. H	Virginia A. & M. College, Blacksburg, Va.
Tewfik, Salah-El-Din	P. O. Box 126, College Park, Md.
Tezier, Tezier Freres	27 Avenue Gambetta, Valence (Drone) France
Thomas, H. Rex	Bureau of Plant Industry Station, Beltsville, Md.
Thomas, Walter	Pennsylvania State College, State College, Pa.
Thompson, A. H	U. S. Dept. Agr., Wenatchee, Wash.
Thompson, H. C	Cornell University, Ithaca, N. Y.
Thompson, Miller	Box 136, Conyers, Ga.
Thompson, R. C	U. S. Dept. Agr., Washington, D. C.
Thornton, S. F	F. S. Royster Guano Co., Norfolk, Va.
Ticho, Robert	P. O. Box 264, Jerusalem, Palestine
Tiedjens, V. A	Virginia Truck Exp. Sta., Norfolk, Va.
Tillson, Albert H	1022 N. Edison St., Arlington, Va.
Tompkins, John P	N. Y. Exp. Sta., Geneva, N. Y.
Toole, E. H	Bureau of Plant Industry Sta., Beltsville, Md.
Townsend, P. C	Selbyville, Del.
Trotter, A. R	Assoc. Seed Growers Inc., Robstown, Tex.
Tucker, W. C	American Embassy, Rio de Janeiro, Brazil
Tufts, W. P	University of California, Davis, Calif.
Tukey, H. B	Michigan State College, East Lansing, Mich.
Tukey, Loren	Hort. Dept. Michigan State College, E. Lansing, Mich.
Turnquist, O. C	University Farm, St. Paul, Minn.
Turrell, Franklin M	University of California, Riverside, Calif.
Turrentine, J. W	1155 16th St., N. W., Washington, D. C.
Tussing, E. B	Ohio State University, Columbus, Ohio
Ulrich, Albert	University of California, Berkeley, Calif.
Upshall, W. H	Vineland Station, Ontario, Canada
Vanderwal, Dirk, J	444 Newton St., San Fernando, Calif.
Van Horn, C. W	University Experiment Sta., Yuma, Ariz.
Vannah, H. P	Box 200, Pisgah Forest, N. C.
Van Overbeek, J	Shell Oil Co., Modesto, Calif.
Vanselow, Albert P	University of Calif., Riverside, Calif.

Vierheller, A. F.	University of Maryland, College Park, Md.
Vincent, C. L.	State College of Wash., Pullman, Wash.
Volz, E. C.	Iowa State College, Ames, Ia.
Wade, B. L.	U. S. Vegetable Breeding Lab., Charleston, S. C.
Wadhams, Corinne	Rowayton, Conn.
Wadleigh, C. H.	U. S. Salinity Lab., Riverside, Calif.
Walkden, H.	Derbyshire Rd., Manchester, England
Walker, L. C.	Lampasas, Texas
Waltman, C. S.	University of Kentucky, Lexington, Ky.
Wander, I. W.	Citrus Exp. Sta., Lake Alfred, Fla.
Ware, L. M.	Alabama Polytechnic Institute, Auburn, Ala.
Warne, L. G. G.	University of Manchester, Manchester, England
Warner, R. M.	Calif. Fig. Inst, Rt. 1, Box 431, Fresno, Calif.
Warren, G. F., Jr.	University of Wisconsin, Madison, Wis.
Watson, Donald P.	Cornell University, Ithaca, N. Y.
Watson, R. R.	PO Box 129, Twin Falls, Idaho
Watt, A. W.	P. O. Box 70, West Summerland, B. C.
Watts, R. L.	Penna. State College, State College, Pa.
Weeks, Walter D.	University of Mass., Amherst, Mass.
Weinard, E. F.	Hort. Dept. Univ. of Ill., Urbana, Ill.
Weinberger, J. H.	U. S. Hort. Field Lab., Ft. Valley, Ga.
Welch, J. E.	University of Calif., Davis, Calif.
Went, F. W.	California Instit. of Technology, Pasadena, Calif.
Werner, H. O.	University of Nebraska, Lincoln, Neb.
Wester, H. V.	Department of Interior, Washington, D. C.
Whitaker, T. W.	Box 150, La Jolla, Calif.
White, D. G.	U. S. Subtropical Fruit Sta., Orlando, Fla.
White, R. H.	Box 93, Harlingen, Texas
Whitehouse, W. E.	Bureau of Plant Ind. Sta., Beltsville, Md.
Whitinger, C. B.	Dept. Agr., Mount Vernon, Wash.
Wiggans, C. C.	University of Nebraska, Lincoln, Neb.
Wiggin, W. W.	Ohio University, Athens, Ohio
Wilcox, J. C.	Dominion Experiment Sta., Summerland, B. C.
Wilde, John E.	Blissfield, Mich.
Williams, H. Hamilton	1235 E. 101st St. Los Angeles 2, Calif.
Williams, W. O.	University of Calif., Davis, Calif.
Windham, Steve L.	Mississippi State College, State College, Miss.
Wingert, John B.	343 So. Dearborn Street, Chicago, Ill.
Winkler, A. J.	University of California, Davis, Calif.
Winter, J. D.	University of Minnesota, St. Paul, Minn.
Winters, Harold F.	Federal Exp. Sta., U.S.D.A., Mayaguez, P. R.
Wischhusen, J. F.	Manganese Research & Development Foundation, Cleveland 10, Ohio
Wittwer, Sylvan H.	Mich. State College, East Lansing, Mich.
Wolf, Emil A.	Purdue University, Lafayette, Ind.
Wood, J. F.	1002 Sec. Natl. Bank Bldg., Houston 2, Texas
Wolfe, H. S.	University of Florida, Gainesville, Fla.
Woodard, Otis	Georgia Coastal Plain Exp. Sta., Tifton, Ga.
Work, Paul	Cornell University, Ithaca, N. Y.
Wright, R. C.	Bureau of Plant Industry, Sta. Beltsville, Md.
Wyman, Donald	Arnold Arboretum, Jamaica Plains, Mass.
Yager, L. A.	South Dakota State College, Brookings, S. D.
Yarnell, S. H.	U. S. Regional Veg. Breed. Lab., Charleston, S. C.
Yates, H. O., Jr.	New Camden Vocational Sch., Merchantville, N. J.
Yeager, A. F.	University of New Hampshire, Durham, N. H.
Yeatman, John N.	Univ. of Calif., Los Angeles 24, Calif.
Young, Robert E.	Mass. Experiment Sta., Waltham, Mass.
Zarger, Thomas G.	T. V. A., Norris, Tenn.
Zielinski, Quentin	Oregon State College, Corvallis, Oregon
Zimmerman, Floyd S.	641 Washington St., New York City

Zimmerman, P. W........Boyce-Thompson Inst., Yonkers 3, N. Y.
Zucker, Isabel........ 1708 Crooks Rd., Royal Oaks, Mich.

JUNIOR BRANCH MEMBERSHIPS

A. & M. College of Texas, College Station, Texas
The Clemson Agrl. College, Clemson, South Carolina
Michigan State College, East Lansing, Mich.
Purdue University—Junior Branch, Lafayette, Indiana
Wisconsin State Hort. Soc., 424 University Farm Place, Madison 6, Wisconsin

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